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BIOLOGY AND HUMAN AFFAIRS



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PREFACE

A BOOK is its own best explanation of its reason for being, and the experienced teacher into whose hands this one falls will form his own opinion of its value as a teaching help. Nevertheless, a few prefatory remarks concerning the present volume are offered as an aid in a first examination of it. The purpose is to direct attention to some of the wider educational values sought and to point out what the author regards as important or characteristic features of his work.

It is axiomatic that except in the tool subjects, where the acquisition of techniques and skills is the objective, much of the value of any school course depends on its organization and direction and on the mass effects it achieves. There has, therefore, in the making of this book been an attempt to select and arrange the material in such a way that the course as a whole will leave the student with certain important appreciations, concepts, and attitudes. As an examination of the book will show, the effort has been made to develop an understanding of the method and scope of biology and an appreciation of the importance of extending its applications to human social affairs. Special attention has been given to building a conception of biology as a practical subject that is to be applied and used; so more than is customary in biology textbooks the subject has been presented in terms of human living. These larger outcomes have been sought because it cannot be assumed that they will necessarily or even usually follow as indirect results of ordinary teaching. They must be planned for and worked for as we work for a command of the facts and an understanding of the principles This book contains the materials for a high school of the subject. biology course organized with these wider educational objectives in view.

In the method of presentation it will be found that the book follows a balanced middle course. The three ways of teaching biology are the type method, the systematic or group method, and the principles method. Each method has its advantages, and when used alone its weaknesses. A word concerning each of these different methods will contribute to an understanding of the organization plan followed in this book.

In the type method a series of representative forms are studied, and as opportunity offers, biological principles and ideas are introduced and the forms under study used to illustrate the principles. The study is inductive, the generalizations growing out of the con-

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crete material. The types are chosen for their illustrative values and the principles are hung to the material in appropriate places as the course proceeds. The strength of the method is its concreteness. Its weakness is that the principles are likely to be lost in the mass of facts so that the course degenerates into a series of lessons that lead to no important educational goal.

The systematic method is that of the naturalist who names and classifies his specimens, and of the museum biologist who arranges and studies his materials by groups. This plan of study gives contact with a wide variety of living material and arouses great interest in some nature-minded pupils. It gives as nothing else can a general first-hand view of the living world, and has especial value for the light it throws on species and group origins and group relationships. It has been said that a biologist is one who understands the unity of life. The study of organisms by groups develops this conception of the living world.

The principles method implies the selection and stating of important principles and ideas as themes, and then selecting from the wide field of biology appropriate type forms and groups to illustrate The thesis is the well-founded one that we cannot the principles. remember the myriad isolated facts of biology and that we should therefore marshal facts back of conclusions and principles which we can remember and use as guides in our thinking. The strength of the method is that it throws emphasis where value is greatest. weaknesses are several. One is that it is not the natural approach of the average pupil to the living world. A second is its abstraction. It seems to be universal teaching experience that principles are elusive and attempts to present them leave the class with a feeling of baffled discouragement unless the presentation is preceded or is accompanied by concrete studies of the illustrative material. understanding and appreciation of the principles do not follow from a mere statement of them.

The three methods mentioned above are not exclusive of each other. In all elementary biology courses each of them is employed to a greater or less degree. The author has used each of them as has seemed to him wise and he has blended them more than is customarily done. The larger organization is in the main by principles. At the same time, in the development of the principles, concrete studies of types and groups are carried out that remove the abstractness and give the values of the other methods. In the early units especially, the studies of the illustrative materials are quite extended in order that these materials may become familiar

PREFACE

and the generalizations based on them assume reality and validity. One rather distinctive feature of the present volume is the use of groups as well as individual types to illustrate general biologic ideas. The advantage of this plan is that by it the student becomes acquainted with a wider range of forms and gains something of the over-all organized view of the plant and animal kingdoms that is so desirable.

More material has been included in this textbook than an average class can cover intensively in a year. One reason for providing this abundance of material is the general desire for more scope in our school work — the belief that extension as well as intension is called for and that we should get away from brief, skeletonized courses that are made up chiefly of memorized facts and definitions. Another reason for an ample textbook is the necessity of caring for classes of rapid learners who require much material to keep them Other advantages are that the textbook itself provides enrichment material where library facilities are inadequate; that it furnishes a basis for special individual and group projects beyond the regular class work that interested students may carry out; that it permits adaptation of the course to the requirements of different courses of study and to regional and seasonal differences in the plant and animal forms available for study; and that it insures to teacher and class a very considerable freedom of choice as to what they shall do.

To the writer, this last consideration is a very important one and he has tried to prepare a textbook that will allow the teacher to conduct the class in his own way. The units are in the main independent of each other and after the course is under way they can be taken up in practically any order. Those teachers who prefer to underlay the course with a foundation of plant study and to take full advantage of seasonal opportunities by studying mosses and ferns, seed distribution, and the light relations of leaves in the fall will find no difficulty in following their customary plan. Enough material on the animal and plant groups has been provided to allow a systematic study by groups if this is considered desirable. The effort of the author has been to produce a textbook that will serve as a source of information and will indicate meanings, and not one that will be used as a recitation guide.

As all biology teachers know, there are great individual differences in language ability of students and the vocabulary problem in biology teaching is therefore a perennial one. Because scientific terms stand as a wall of words between some students and the vi PREFACE

subject, the number of them has been kept to a minimum in this presentation. For those desiring a larger technical vocabulary, additional terms are given in the glossary. The derivations of many of the terms are given in the text because these are helpful to some students and may be skipped by others. A list of comprehension questions for those who need them as a guide in reading is appended to each unit. More detailed directions for activities than can be included in the textbook, and questions and tests requiring applications of facts and principles, are given in a workbook to accompany this text.

Acknowledgments

For reading of the proofs of portions of the book or for photographs supplied for illustrations the author wishes to acknowledge his indebtedness to the following:

To Professor Carleton S. Coon of the Department of Anthropology, Harvard University, for extended and invaluable assistance with the material relating to the races of men and for photographs used in connection with this material; to Professor Robert M. Yerkes, Laboratories of Primate Biology, Yale University, for reading and correcting errors in the proofs of the section dealing with monkey and ape society and for photographs used in this section; to Dr. Joseph Kubis of the Psychology Department of Fordham University, for reading the proofs of the pages dealing with the emotions and for the sample record made by the emotion detector; to Professor Elbert C. Cole, Department of Biology, Williams College, for reading and making corrections in the units on "Types of Water Animals" and "Life in the Sea"; to Mr. Tunis Baker, New Jersey State Teachers College, Paterson, for a critical reading of the glossary; to the editors of Nature Magazine for most generously supplying a large number of photographs from their files: to my workbook co-authors, Mr. Chapin W. Day of the Caldwell, New Jersey, High School, and Miss Margaret Ritchie, formerly teacher of science in St. Agnes School, Albany, New York, for extended help and advice; and to various persons who have contributed photographs or drawings, credit for which is given in immediate connection with the illustrations. Manifestly such a volume as this embodies suggestions from many sources, and the author wishes to express his gratitude to those unmentioned others who have paused in their own work to extend to him a helping hand.

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INTRODUCTORY

"For the biologist, after all, is handling the greatest thing on earth—life itself." John D. Dyer

THERE is a substance in the world that, like fire, consumes. As a flame is fed and spreads by the fuel it destroys, so this strange substance is supported and increases in amount from the materials it devours. Its capacity for growth seems illimitable. It covers the face of the land, burrows and multiplies in the soil, spreads itself through the vast reaches of the sea. It is a curious substance, quite unlike anything else that we know. Of course we are referring to the living material of which we and all other living things are made.

What is the difference between living and non-living material? What is life?

We do not know. We cannot define life. We cannot observe it directly. Its origin and nature are mysteries that lie behind an unlifted veil. But we do have a great science that deals with living things. We have accumulated a vast body of knowledge concerning the forms in which life expresses itself and the processes by which it maintains itself. This science is called biology. Its field is the living world, from the simplest little plants and animals up to and including man. Our course in biology will be a study of living things.



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Williston Academy, Easthampton, Massachusetts

WHY WE STUDY BIOLOGY

Biology teaches the method of science and it is more intimately connected than any other school subject with human lıfe.

> "The human race has more and greater benefits to expect from the successful cultivation of the sciences which deal with living things than from all other sciences put together."

CHARLES W. ELIOT

REASONS FOR STUDYING BIOLOGY

QUESTIONS FOR CLASS DISCUSSION

What school subject deals most with the things you do and think about day by day?

What school subject deals most with the things that have the greatest interest for you?

EACH study in the school course is supposed to be of some particular benefit to those who take it. History tells the story of the past and when we read it aright it helps us to avoid the mistakes that other peoples have made. English opens the literature of our civilization to us and teaches us how to express our own thoughts. Civics discusses our problems of government and the best ways of solving them. Mathematics trains us to think quantitatively (exactly how much or how many) and how to go through with straight, cold logic to true conclusions. What place has biology in the educational scheme? What training, information, or outlook does it give that is especially valuable? Among the reasons that may be given for the study of biology are the following:

Biology is a science and if it is studied in the right way it gives mental training of the highest value. A course in this great science gives opportunity to practice the method of thinking and working that scientists use in making their discoveries. The study of it frees the mind from superstitions and false assumptions and helps to build the scientific attitude of mind.

Biology has countless applications in practical human affairs. Its field is the whole living world, and it has many applied daughter sciences. Hygiene and medicine are branches of it. Human and animal feeding, plant and animal breeding, crop production, forestry, the protection of fisheries, and the preservation of wild life all come within the scope of biology. Psy-

chology and anthropology are branches of biology and in a wide sense we may look on history and government as phases of biology, for they deal with the behavior and the activities of man and man is a biological being. No other science touches our lives so intimately and in so many ways as does biology. It helps us to control our environment and to make the world a better place in which to live. The science of biology is not a mere mass of facts but an attempt to interpret the laws of life.

Biology is a guide in life. It helps us to understand our place in nature and how to live in harmony with nature. It leads us into ways of living that are satisfying to our instincts and desires.

Biology furnishes fundamental ideas that serve as guiding principles in social and political thinking. It helps those who understand it to approach the problems of human relationships in a scientific spirit and to see these problems in a scientific light.

In science we are not asked to accept assertions without evidence for their correctness. We shall therefore present for consideration certain facts in support of the statements that have been made above.

Problems in Unit 1

- 1 What is the scientific method and why is it important?
- 2 What are the characteristics of the scientific mind?
- 3 How important is biology as a mental liberator and as a safeguard against false ideas?
- 4 How does biology help us to control and improve our environment?
- 5 How does biology help us to adjust ourselves to the world?
- 6 How does the study of biology aid in the satisfaction of our instinctive desires?
- 7 What help can biology give in the solution of our social problems?

PROBLEM ONE

What Is the Scientific Method and Why Is It Important?

"If our public schools, through which now pass the whole of the oncoming generation, could only get the objective scientific technique started, we could change in one generation the whole history of the United States and banish the terrible fears which are rife among all classes of our citizens as to the future of democracy."

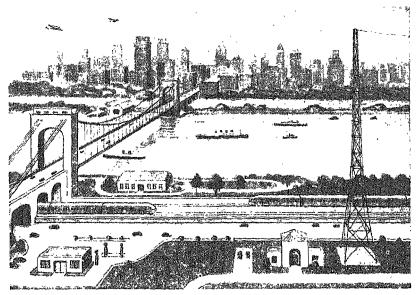
ROBERT A. MILLIKAN

Up to about 200 years ago the world moved slowly along. Then the scientists got busy and set everything into a whirl. The steam engine, the steamship, the locomotive, the gasoline engine, the automobile, and the airplane followed each other in swift succession. Electricity was put to work and the telephone and radio appeared. Machine after machine entered our factories and poured forth goods at an undreamed-of rate. Hundreds of new and useful products were made by chemists. More efficient ways of doing things were devised. Agriculture was revolutionized. Populations doubled and doubled again. Cities grew like mushrooms because new methods of transportation were found and disease was controlled.

Why did all this happen? It was because of the discovery and use of the scientific method of work and investigation and the growth of the scientific mind. *Men discovered how to make discoveries*. They did not become more intelligent but they learned how to use their intelligence.

The scientific method. The scientific method is a way of finding what is true and what is not true. Essentially it consists of gathering facts and then checking or testing the truth of explanations and ideas and statements by these facts. An illustration will help make clear what the method is and how it is used.

We see a plant that has been blown over in the garden. The stem bends upward so as to make its tip grow erect as before. Why does it do so? We know that if we set a plant in the window



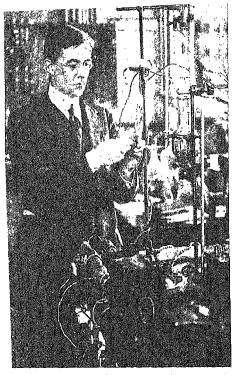
Man now flies more swiftly than the birds. His voice is heard to the ends of the earth. After the discovery of the scientific method of thinking and working, scientists quickly made a new world.

the leaves turn to the light. Perhaps it is the influence of the light that causes the stem to turn up.

Now we have made a guess as to the cause of the bending upward of the stem. We have what scientists call a *hypothesis*. It is a possible explanation, but it may or may not be the correct one. The scientist will not accept it until he *knows* that it is correct; so to be scientific we must test the truth of our hypothesis. This we can do by an experiment.

We can lay a potted plant on its side in the dark. If there is no upward bending in the dark, then we may reasonably conclude that our hypothesis is correct. But if the stem turns up without light, we know that our explanation is wrong. Something besides light must be the cause of the upward bending. Test this hypothesis for yourself. You can either place your plant in a darkened room or cover it with a tight box.

Example of use of the scientific method. Until a little after 1800 smallpox was the worst disease of man. Nearly



The essential feature of the scientific method is the testing of ideas by facts to see if they are true. One method of collecting facts is by experiment.

everyone had to come through it, and it was deadly indeed. Century after century the loathsome scourge ran on, taking from every generation of men its heavy toll. Then all at once it sank to a very minor place among the ills of mankind. Why was this?

In London 150 years ago, a great physician and surgeon, a Scotchman by birth, was teaching medicine. His name was John Hunter, and he did much to introduce the scientific method into medicine. His motto was, "Don't think, try." One of his pupils was Edward Jenner, who had grown up in a country region and returned to it to practice.

Of course one of the diseases that the young physician met

was smallpox. So common was it and so sure were people to take it, that it was customary to inoculate those who had not yet had it with virus from a mild case. This was on the theory that there were mild strains of smallpox and malignant strains, and that it was better to get the infection from a mild case and be protected against the disease than to risk a later virulent attack. The trouble with the practice was that the attack following the inoculation was likely to be severe and it was not at all certain that death would not result.

Jenner knew that cows have a disease called cowpox. He learned also that those who milked cows could get this disease, which showed itself merely as sores on the hands or on places on the skin scratched or touched by the hands. Jenner found also a belief among the country people that those who had contracted cowpox were protected against smallpox. A milkmaid had

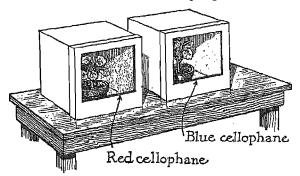
said to him, "I am not afraid of smallpox because I have had cowpox."

Here was a hypothesis, and the young physician had reason to believe it might be correct. "Don't think, try," was the advice of his great teacher. So Jenner decided to apply the scientific method and test his hypothesis.

He inoculated a boy with cowpox. Then after the cowpox (or what we call vaccination) had run its course, he inoculated the boy with smallpox virus from a mild case. As the boy did not contract the disease, Jenner took him along when he visited cases of smallpox. Again the boy proved himself immune; so Jenner vaccinated other persons with cowpox virus. They likewise became immune to smallpox, and a little before 1800 Jenner published his results. Of his own work he wrote, "Before announcing my discovery to the world I placed it on a rock from which it could not be moved."

It is still on the rock. Every nation in the world uses vaccination to prevent smallpox. It is because of Jenner's discovery, and only because of it, that you and your classmates are safe from what was once man's worst disease.

A second example. One of the truly great scientists of all time was Louis Pasteur; more than any other one man he was the founder of the science of bacteriology. He worked out a method of protecting cattle and sheep against a disease called



You know that leaves turn to the light. Find by experiment whether they are equally affected by light of different colors.

anthrax by vaccinating them, but bacteriology was new and the government officials did not believe in his work. Pasteur did not try to convince them by argument, but proposed that the matter be decided in the scientific way.

Fifty sheep were secured. Pasteur vaccinated twenty-five of them with weakened anthrax germs. Then all the sheep were inoculated with virulent anthrax germs. The vaccinated sheep lived. The others died. The experiment proved that Pasteur was correct and that the vaccination protected the animals against the disease.

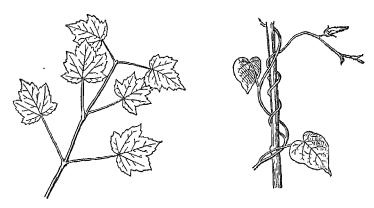
Importance of fact finding. In these historic examples of the use of the scientific method the essential step was getting the facts — the exact, indisputable facts — by which the theory could be tested. This is the central feature of the method of science. Theories and opinions are man-made and may be wrong. Facts are immutable and are themselves the standard for determining what is true. A great scientist in speaking of the overturning of a scientific theory referred to it as "another example of a beautiful theory slain by an ugly fact." Like other scientists,



he knew that when it comes to a choice between a fact and a theory the theory must go.

How important a part of their work scientists consider fact finding to be is shown by the way they work at collecting facts. In research laboratories thousands of scientists are daily carrying on experiments to find facts. Weather observers all over the earth are collecting facts relating to the

A second way of obtaining facts is by observation. By this method the scientist shown at the left is gaining information about birds. condition of the air. Astronomers scan and photograph the heavens to gather new facts about the celestial bodies. Geologists tramp the earth to learn more about it. At their proving grounds automobile engineers are testing their ideas by facts to see if they are sound. In one recent year 32,000 papers in



Will the twigs on a tree that are now bearing leaves ever bear them again? Do all twining vines wind about their supports in the same direction? By observation answer these questions for yourself.

chemistry and 10,000 in biology were published, most of them reporting new facts. Scientists know that if we reason from false facts or without facts we cannot hope to reach truth. The chief treasure of the world is the tested and proved body of scientific facts that we now have.

The scientific method the better way. "By their fruits ye shall know them." The test of any way of doing things lies in the results that are secured. Let us, as is customary in science, allow the facts to speak for themselves as to the value of the scientific way.

After the introduction of the scientific method the world changed more in 200 years than in all previous human history. It has changed more since 1900 than in the 300 years that went before. Men now fly more swiftly than the birds. Their voices sound to the most distant parts of the earth. New chemical products are created. Disease is in large part conquered. In all

fields where the scientific method is used truth is learned and we progress with great strides.

Are we making the same progress in fields where the scientific method is not applied? We are not. In many fields of human effort, in spite of much activity and great changes, we have made no advance at all. Within your lifetime much of the world in its government has not only failed to advance but has gone backward a thousand years. The facts all about you proclaim that the method of the scientists is the fruitful way. There is nothing so important for the world as that the scientific method be adopted in all the affairs of mankind. "Science is not wholly for men of science but for all the people."

The word "science" is from the Latin scire, to know. In the root meaning of the word, science is anything we know, and science need not be confined to any particular field. Yet often we speak of physics, chemistry, biology, geology, and astronomy as "the sciences." We do this because it was in these subjects that the scientific method came into use and is now habitually used, and because it is in these fields that we best know our facts and think most rigorously in the scientific way. We are gradually extending the use of the scientific method to new fields, but as yet the best place to learn it is in the old science shop. Here the method is working at its best. Here it is now easiest to work without rousing the emotions and prejudices that are so confusing to the mind. Biology is a science and it offers you an opportunity to learn not only the facts of biology but also the scientific way.

PROBLEM TWO

What Are the Characteristics of the Scientific Mind?

"The scientific attitude of mind consists in an honest endeavor to receive the truth whatever its nature and source." H. H. LANE

The scientific method is a search for truth. The scientific mind is a mind that desires to know truth and is willing to accept truth when it is found. No mere human has or can hope to have a mind that is wholly scientific in its outlook, for it is natural for our emotions, sentiments, hopes, and desires to influence our thinking. A completely scientific mind is an ideal that we can only hold before us and strive to reach as nearly as we can.

The scientific mind an open mind. One of the bad qualities of many minds is that they resist new ideas. Often the possessors of these minds resent any opinions different from their own. They want no new facts brought in that will upset their old beliefs. They may persecute those who differ from them intellectually and deny them freedom to set forth their ideas or the proofs of them.

This closing of the mind to new and different ideas is completely opposed to the scientific way. The scientist, so far as he embodies the spirit of true science, welcomes new facts and new interpretations of facts. He knows that what we know is only a small fraction of what we will know. He honors most the scientific men who lead on to new things most rapidly. In the field of science there is complete intellectual freedom, so that if even the humblest scientific worker has new facts to present or new ideas that promise to be true in the light of old facts he is welcomed and listened to. The world of science is a great court in which the only question asked is whether a proposition or a statement is or is not true.

The scientific mind is critical. The scientific mind is an open one, but it is also an exceedingly critical one. New ideas are welcomed by it, but they are given the most searching of examinations before they are accepted. Of all people, scientists are the slowest to come to hard-and-fast conclusions. They hold many questions open and do not try to come to conclusions on them at all because they do not have enough facts to decide them with reasonable certainty.

To a non-scientific person scientists usually seem too skeptical, too conservative, too slow to act. Often they vex those not trained in science because they refuse to accept ideas for which there is not sure proof and will not give their support to plans that have not been proved to be sound. Popular leaders and other "men of action" customarily look on scientists as being too cautious and too inflexible for practical purposes. Yet, as we have seen, science advances more rapidly than anything else.

The reason for this is that a scientist very carefully studies out what he is doing and when he moves, even though it be but a step, he goes forward. Where the method of science is not employed we do not know what we are doing and instead of progressing we wander aimlessly about, going sidewise or backward as often as we advance. The ancient Greeks had no word for progress, but spoke of new ideas and new ways of doing things merely as change. We rightly have much the same attitude toward many of the innovations in our social and political life. It is only in science that knowledge and effort are cumulative. It is only in science that change and progress mean the same. Science advances because it rests on a foundation of proved facts and each generation can build on what has been done before.

An opinion as to the value of scientific thinking. Here are the words of the writer, H. G. Wells, concerning the thinking of scientific men:

"When the intellectual history of the nineteenth century comes to be written, nothing, I think, will stand out more strikingly than the empty gulf in quality between the superb and richly productive scientific investigations that are going on and the general thought of the other educated sections of civilized communities. I do not mean that scientific men are, as a whole, a class of super-

men, dealing with and thinking about everything in a way altogether better than the common run of humanity, but in their field they think and work with an intensity, an integrity, a breadth, boldness, patience, thoroughness, and faithfulness which puts their work out of all comparison with any other human activity. In these particular directions the human mind has achieved a new and higher quality of attitude and gesture, a veracity, a self-detachment, and self-abnegating vigor of criticism that tend to spread out to every other human affair."

Note that the writer of the above has not said that scientific men are superior to other men. He has said that the way they think and work in their own field is superior. It is a method, and not men, that is being discussed. There is no claim that scientific men know everything, but that they have a method and a way of thinking that have given wonderful results where they have been used.

The scientific mind needed in a changing world. In earlier times the world changed only slowly. Men discussed matters that interested them, but they had no way of settling them. They guessed at their facts, allowed their wishes and

prejudices to enter into their thinking, and often accepted as final proof what someone else had said or written. They made no sharp distinction between what was known to be true and what was only supposed or believed to be true. In consequence each generation knew

A scientific attitude toward the conditions of a changing world. When the occupation of the older man shown in the illustration vanished, he faced reality and began training that would fit him for new work.



little more than the one that had gone before and the conditions under which men lived changed only slowly. By experience people learned to meet the slow changes that came to them. Gradually they adapted themselves mentally to the new ideas that were advanced.

Now all is different. You live and will live in a changing world and you must be able to change with it. No longer can a man be sure that he can do the same kind of work all his life. No more can he expect to get himself settled in some one method of doing things and then keep on in a routine way. Mentally he must be prepared to see things as they are; to adjust himself to new ideas and to accept new conditions, new methods, and new work. This is a scientific age and only those who are able to think in the impersonal, sure, scientific manner are fitted to meet the changes that it brings. Many young people are now being trained in scientific thinking and you will need a scientific mind to hold your place in competition with them.

The scientific mind is a mind fitted to use the scientific method. The best way to acquire it is by the use of this method. You can use the scientific method in your study of biology. You can use it in your daily life. You can learn to gather the facts in regard to matters you are called on to consider. You can learn to be guided by facts. We change by use, and if you act like a scientist you will tend to become one and to have a scientific mind.

PROBLEM THREE

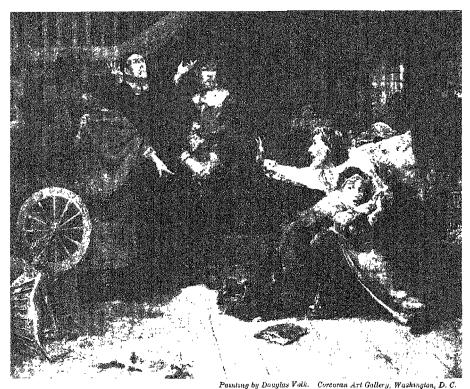
How Important Is Biology as a Mental Liberator and as a Safeguard against False Ideas?

"Science is the great antidote to the poison of enthusiasm and superstition." ADAM SMITH

Most untrained minds will accept statements as true when there is no proof that they are true. This is a bad weakness in the human thinking mechanism. One result of it is that every group of people build up superstitious beliefs which enslave and often degrade those who hold them. A second result is that false statements and ideas concerning all kinds of subjects are spread and accepted as facts and thus to a considerable degree men are made to live in a world where there is no distinction between the false and the true. One of the great missions of science is to free mankind from the superstitions of the past and to harden the mind against the acceptance of untested assertions and schemes of thought that are launched in the present.

Belief in witchcraft. Among practically all savages there is a belief in witchcraft. In civilized nations also until recently it was generally accepted that certain persons were in communication with the spirit world and by incantations or charms could bring good or bad fortune. Among European peoples it was common for women to be singled out as witches and accused of being in league with evil spirits. It was believed that such a woman could take the form of a black cat or of some other animal; that she could ride through the air on a broom; that she could raise storms on the sea; or that she had an evil eye that would bring bad luck or sickness to those on whom it fell.

There was never any proof that any of these things are true and people of sound minds never should have believed them. Yet they did and do believe them and this belief has meant misery for millions of lives. Estimates of the number of persons put to death as witches in Europe within historic times vary from 100,000 up to several millions. Hundreds of thousands more



Accused of witchcraft. In past centuries such scenes were common. Only the influence of science prevents their still being enacted in our midst.

have been tortured. Millions of others have been accused of witchcraft and made miserable by the persecutions from their neighbors that followed. In Massachusetts only about 250 years ago twenty persons were officially put to death as witches in accordance with the English law of that time. In 1933 two boys in Pennsylvania killed an aged woman because they believed she had "hexed" their cow. We need scientific knowledge and scientific thinking to keep us out of matters of this kind.

Belief in astrology. Astrology takes it for granted that the sun, moon, planets, and brighter fixed stars have a great influence on the personal affairs of men. This superstition grew up in ancient Babylonia when there was a belief in many gods and it was thought that a different god was associated with each planet or star. From Babylonia it spread to Egypt and Europe and so came to us. To pay money for horoscopes is an utterly senseless thing to do, but many of our people still go to astrolo-

gers and wonder if it would not be better to wait about beginning some undertaking until Jupiter or Mars changes its position in the sky.

This superstition has done much harm. It was for long a very bulwark of the doctrine of the divine right of rulers. Even

yet certain men proclaim a belief in their "stars" and announce that by destiny they are selected to lead and rule, and other men accept these ideas and like sheep follow adventurers into the most senseless undertakings. In addition, astrology helps to make of man a creature who cringes before unseen forces instead of standing erect on his own feet and trying to take care of himself.

When a London morning newspaper omitted its horoscope one day not long ago, the editorial office received more than fifty thousand telegrams, telephone and personal calls within twenty-four hours from complaining readers.

The clipping above (from Collier's, The National Weekly) reveals the hold that astrology still has on the English popular mind. In our own country 150 newspapers carry astrological services. No scientific subject can hope to arouse the interest that is displayed in this hoary superstition of the past.

It encourages him to think that he is helpless in the hands of fate instead of living in a world of laws to which man can adapt himself and in which by his own efforts he can make himself secure.

Prevalence and evil of superstitions. Up to a few hundred years ago superstition hung like a miasmatic fog over the whole earth and even yet it envelops much of mankind. India is fettered with a belief in a hereditary caste system and with a multitude of smaller superstitions that go with this malignant doctrine. China lives in dread of flying dragons and demons. More primitive peoples accept all sorts of ideas about the powers of conjurers and medicine men. Among us fortune tellers, palmists, numerologists, and crystal gazers flourish and love charms are sold. Back through history it has been the same. The ancient Greeks, brilliant as they were, were afraid to go into battle without the permission of an oracle, and the practical Romans were guided in the most important affairs by the appearance of the internal organs of animals and the flight of birds.



Ewing Galloway

There is great need that the crusade for scientific thinking be pressed onward. Not only astrologers but also crystal gazers and other revealers of the future flourish among us. We may smile at such superstitions, but the practices that accompany them in real life are far from amusing. Wholly innocent persons put to death because of malicious charges against them, human sacrifices, and women throwing their babies to the crocodiles to appease the angry river gods are the kind of things we find in a scienceless world.

How science destroys superstition.

Science destroys superstition in two ways. First, it offers explanations of a kind that make superstitious explanations seem absurd. It replaces them with something better. It is natural for the human mind to seek reasons and explanations, as is shown by the fact that the most ignorant savage has an explanation of why the wind blows, why the sea is salt, why volcanoes erupt and earthquakes occur. Science satisfies the natural desire of the human mind to know why.

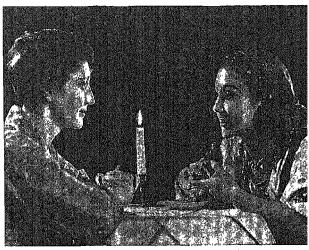
Second, science builds a type of mind that refuses to accept superstition. In sciences we accept only that for which there is proof, and because superstitions lack evidence in their support they are out. The scientific thinker prefers no explanation to one that has merely been made up. In the hard soil of the scientific mind it is difficult indeed for superstition to strike root.

A safeguard against misleading propaganda. It is now much easier to establish and maintain a tyranny than it was in the days of Sargon or of Genghis Khan; a grave new danger has come to mankind. Over a radio a whole nation can be addressed at once. Accounts of happenings can be flashed to

distant parts of the earth and made to appear in newspapers everywhere. The technique of arousing and organizing masses of people and of setting them against other classes or peoples has been greatly improved. We now have nationwide or even worldwide systems of propaganda designed to rouse the emotions of people and to direct their actions along certain ways. Propaganda threatens to reduce civilized man to a mental servitude as degrading as that enforced by the superstitions of the past.

The best defense against irresponsible propaganda is the tough-minded intellectual attitude of the scientist. If anyone has an idea that he claims to be good he should be asked to cease his professions of righteousness and his name calling and give proof of the excellence of what he advocates. Attention should be centered on the facts and ideas of the propagandist and not on somebody or something else. The rule in industry is, "Do your experimenting in the laboratory and your manufacturing in the factory." Only one out of scores of ideas that are suggested works out and everything must be tested and proved before

it is adopted. So in human affairs in general we are wisest if we examine and test before we adopt and use. A cold scientific analysis of any ideas presented is the best guarantee that the false will be rejected and the true approved. One scientist who worked with a colony of chimpanzees reported that if one of them was pun-



Ewing Galloway

In our national capital there are many licensed fortunetellers. They are patronized by members of the families of some of those high in the administration of our national affairs. ished for wrongdoing and cried out in anger, all the others would howl in unison with him, even when they did not know what it was all about. Instead of howling in unison with propagandists who appear among us, we should subject their ideas and claims to a rigid intellectual test.

The need for science as a conservator of mental freedom is appallingly great; for without science to influence him to winnow and test his ideas and beliefs, man has proved himself but a feeble intellectual organism. He builds up beliefs in the existence of creatures and forces that do not exist at all. Under such beliefs he is ruled by fear and demonology. He is exploited and tyrannized over by mental racketeers who make a pretense of protecting him from evils that exist only in his own imagination. When disease comes he accepts it as fate and bemoans his sad lot. When drought befalls, instead of building irrigation dams or hunting for crops that will withstand the dryness, he wastes his strength in snake dances to bring rain. When propagandists come with false tales, untrained man drinks in their doctrines and allows the fetters to be placed on his wrists. Without science man has always had a complete set of false explanations of the causes of his woes and blessings and he has always failed to do the things that would bring him a happier and more abundant life. All men in all nations should be trained in science so that they will learn to seek and know truth.

PROBLEM FOUR

How Does Biology Help Us to Control and Improve Our Environment?

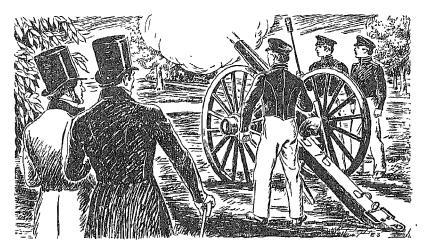
"Science is not a highbrow creed, but a rational and sound philosophy of living." Samuel S. Wyer

In a thousand ways biology is employed to improve the conditions under which men live. Of its application to our problems of material living we shall consider only two — how biology aids in the conservation of health and how it increases the food supply of mankind. You can list for yourself almost countless other ways in which biology has given us better control of our environment and increased the supply of materials that man needs.

BIOLOGY AND HEALTH CONSERVATION

If in the summer of 1853 you had visited a public park in one of our Eastern cities, you would have found a group of men firing a cannon into the air. Yellow fever had broken out in the city and someone had suggested that firing the cannon would prevent the spread of the epidemic. Not knowing anything else to do, the city officials had ordered the bombardment of the air to be carried out. The incident shows how helpless the people of earlier times were in the presence of epidemics of a kind that we now easily control.

Knowledge gives control of disease. The great difficulty that the people who went before us had in dealing with disease was that they did not understand its cause. They were struck down by arrows from the dark and had no idea of what to do to bring them safety. Now science has thrown the light of knowledge on the origin of sickness. We know about germs and how to avoid them. We know how to vaccinate against them and have antitoxins and other serums to neutralize their effects. We have learned about the necessity of vitamins and minerals in our foods and can prevent deficiency diseases. Our modern surgery is a maryel, and a fascinating chapter on the effects of the ductless



Firing a cannon into the air to check an epidemic of yellow fever in 1853. In the fields in which we lack scientific knowledge our present efforts are often as fruitless as was this one in the field of health.

gland secretions is being written; and new medicines are bringing more and more diseases under control.

This advancing knowledge has made possible great progress in the control of disease: discoveries in the fields of sanitary and medical biology have repeatedly shown their effects by decreases All over the civilized world the average life span has in illness. more than doubled in the last 200 years. Year by year life expectancy lengthens and some say that within your generation it will reach 100 years. No longer are our cities ravaged by epidemics of yellow fever, plague, cholera, or smallpox. In the more densely settled areas malaria is under control. Typhoid fever and diphtheria can be prevented. The tuberculosis death rate comes down and down. An appendicitis patient is no longer allowed to die with "inflammation of the bowels," but is promptly operated on and in the ordinary case his life is saved. New remedies and new knowledge enable us to conquer diseases before which we were formerly helpless. In little more than 50 years we have made far more progress in the prevention and treatment of illness than was made during all the previous history of mankind.

BIOLOGY AND OUR FOOD SUPPLY

Somewhat over 140 years ago an Englishman named Malthus wrote a treatise in which he set forth that there must always be hunger and poverty in the world. Malthus pointed out that the ability of human beings to multiply is very great; that always, no matter how great a supply of food is available, the tendency is for a population to gain in numbers until starvation checks the increase. He held that if a greater food supply is provided the population simply grows until the limit of the more abundant food supply is reached and starvation is again faced. The argument of Malthus was that it is hopeless to try to improve the condition of the poor, because the increase of population always keeps pace with any increase in food production. Famines that wipe out surplus populations are part of the natural plan.

The theory of Malthus is correct among peoples who do not employ science in their agriculture, but it no longer has any application in nations like our own. By the use of science we can now increase almost indefinitely the amount of food produced. Notwithstanding the great increase of population in our country we have always been able to produce an abundance of food for all, and now we are returning much of our land to forests because we no longer need it for agricultural use. Let us see some of the ways in which science has increased the world's food supply.

A great discovery. From earliest time men have worked vegetable matter and manure into the land to enrich it for the growth of crops. They believed that the plants took up the fragments of the decaying matter from the soil and from these fragments built their own bodies. About the middle of the last century a German scientist named Liebig decided that this view was probably incorrect. He was a chemist and did not believe that the starch, sugar, oil, protein, and other substances that he found in plants exist in the soil. He believed, rather, that vegetable matter and manures are broken down in the soil until the elements in them are reduced to mineral salts and that plants take from the soil only water and certain mineral sub-



National Fortilizer A granutron

One of the greatest scientific discoveries ever made is that the growth of plants can be increased by the addition of chemical substances to the land. As the cotton plants in the center show, without fertilizer this land would be useless. On the right and left, where fertilizer was applied, a good crop will be produced. The use of chemical fertilizers began less than a century ago, but without them the modern world would be facing famine in a single year.

stances. Out of these raw materials Liebig believed that plants build the many different substances that he found in them.

Liebig put his theory to the test. Near his laboratory was a field that was noted for its sterility. He sowed this with a mixture of mineral salts and had it planted to a crop. The plants flourished in a remarkable manner; the era of chemical fertilizers had opened.

Now millions of tons of fertilizers are used each year. The preparation of them is a very great industry. By their use wornout soils and soils naturally deficient in certain elements are made to produce abundantly. Improving soils by the addition of minerals is a comparatively new agricultural practice, but it has increased amazingly man's supply of food. Without fertilizers it would be necessary to abandon much of the agricultural land of our Eastern states. Without fertilizers the modern world would be in the midst of famine before the end of a single year.

Other ways of increasing food supply. Science increases our food supply not only by soil improvement but by the improvement of cultivated plants and domestic animals, and by

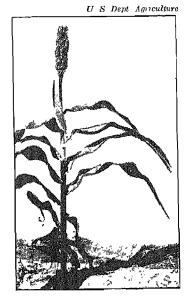
teaching us how better to protect animals and care for them. Plant breeders give us plants that yield more abundantly or are resistant to the diseases that attack them. Animal breeders produce cows that yield more milk, hens that lay a greater number of eggs, meat animals that grow more rapidly. Our plant scientists have brought from South Africa kaffir corn and sorghums that withstand the hot summers of our Southwest and lespedezas from eastern Asia that flourish in the acid soils of the Southeast. We have been taught how to protect our fruits and crops from insects by the use of poisonous sprays and dusts and how to control many of the diseases of domestic animals. All these activities are in the field of applied biology and they enormously increase man's supply of food.

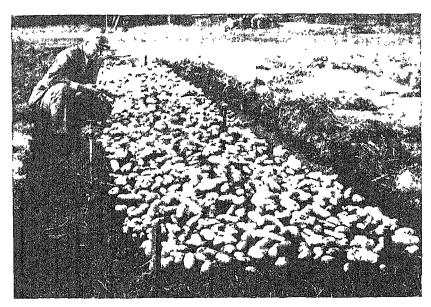
Discovery of how to preserve food. One of the most important discoveries ever made by man is that food can be preserved in cans. This discovery is important because it allows man to lay up food supplies for seasons of scarcity. It makes it possible to transport food long distances so that the salmon of the Alaska rivers or the pineapples of Hawaii may be used to

feed the inhabitants of cities thousands of miles away.

The practice of canning foods grew directly out of the discovery that fermentation and decay in foods are caused by the growth in them of living organisms (bacteria) so small that they are invisible to the naked eye. When this was learned it was quickly discovered that foods could be preserved by

Kaffir corn. A crop from South Africa suited to the hot and dry summers of some of our Southwestern states. An important method of increasing man's food supply is by the importation and breeding of plants suited to different climates and soils.





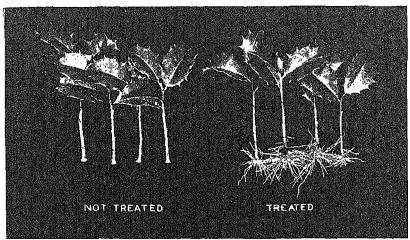
A new method of plant production that greatly increases the amount of food that can be produced on a given area of land. A wire screen was placed over a shallow cement tank that contained water and the minerals needed by the plants; the screen was covered with excelsior and the seed potatoes were laid on this and covered with a second layer of excelsior. The potatoes grew as they appear in the photograph, the yield being at the rate of 140,000 pounds to the acre. Why engage in war for agricultural lands when science has shown how to produce food in such quantities? (Photo from W. F. Gericke's Complete Guide to Soilless Gardening, published by Prentice-Hall, Inc.)

sterilizing them with heat and sealing them in tight containers away from the air. The shelves of any grocery store bear eloquent testimony as to how greatly this discovery has affected modern life. An additional new method of preserving foods is by cold.

A glimpse ahead. Those who are not scientists often fall into the habit of thinking of the world as finished. Such persons would naturally take it for granted that we will always produce our food crops in practically the same way that we do now. This is not necessarily true, for scientists are always discovering something new. We shall mention two lines of investigation that are of the kind that may affect our future food supply.

For a long time experiments have been carried on with a way of growing plants without soil (chemiculture, or hydroponics, it is called) that in the opinion of some of its enthusiastic advocates may make all plans for land use antiquated. It may remove (some say it has already removed) all excuse for nations' trying to extend their territories to increase their food supply. The plan is to grow plants with their roots in water in which the needed minerals are dissolved. This has often been done in laboratories and now efforts are being made to adapt the method to the commercial growing of flowers and vegetables.

When this method is used, less fertilizer and much less water are required than when the plants are grown by irrigation in the open ground. By storage of water, crops can be produced in regions of scant rainfall, and it is possible that the warm, semi-desert parts of the earth will become the chief centers of food production. The tanks are inexpensive to construct and, unlike the soil, they retain all the water and fertilizer for the use of the plants. Sometimes the tanks are filled with sand or gravel so that the roots will hold the plants upright, but the minerals the



P. W. Zimmerman

Effect of a chemical substance in promoting root growth in cuttings of holly. We shall probably soon use chemicals to cause quick growth in domestic animals and cultivated plants.

plants require are dissolved in the water supply. Not all attempts with the method are commercially successful, but as the photograph on page 26 shows, some enormous crops have been produced in this way.

A second possible way of increasing food production is by the use of chemicals that stimulate growth. Some of these are now used to cause the rapid development of roots on plant cuttings, and possibly substances that will cause luxuriant growth in the whole plant may be found. It is possible, too, that by feeding gland extracts or other chemicals to the animals we use for food, they will be made to grow more rapidly or to a larger size. On one fur farm giant minks are now being grown by the use of gland extracts.

Perhaps neither of the methods mentioned above will ever be of any importance in increasing our food supply. Certainly there is no reason to believe that at any time in the immediate future we shall give up our gardens, orchards, and fields of grain and rely only on water tanks for crop production. Neither have gland extracts been employed in the rearing of farm animals. Yet we now have the advantage of all the facts that the scientists who have gone before us have discovered and we know that important changes in the ways we produce our food will come very rapidly. No one can tell what the discoveries of science will be or where they will lead, but we know that in any field in which scientists work great changes are bound to come.

One very important reason for placing biology in the school course is that people in general may have an appreciation of its importance in our daily life. An understanding of biology carries with it this appreciation of its services and gives the ability to use these services. It leads to a willingness to support further investigations in the biological field which are sure to yield benefits of which we do not yet know.

PROBLEM FIVE

How Does Biology Help Us to Adjust Ourselves to the World?

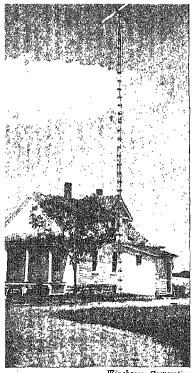
"We can command nature only by obeying her laws."

SIR CHARLES LYELL

We live in the world. We are part of the world and to get along in it we need to understand it and our relation to the other things and people in it. Biology helps us to do this. It impresses on us the necessity of putting ourselves in harmony with natural laws and forces — what we call "nature" — and along with the other sciences it shows us how this can be done.

Unchangeableness of physical nature. Persons often speak of harnessing or mastering the forces of nature. This is likely to lead to a wrong impression and to a wrong attitude toward nature. When we say we have mastered arithmetic we do not mean we have changed the laws of numbers or have acquired the ability to change them. We mean merely that we have gained an understanding of these laws and of how to apply them. So when we speak of mastering nature we mean that we have learned her laws and understand how to arrange matters so that these laws will operate to our advantage.

For the laws of nature are immutable and they operate absolutely without regard to us. The farmer who pipes water by gravity from a hillside spring to his house has not conquered nature. He has merely arranged matters so that the force of gravity will bring the water where he wants it. The engineer who builds a wind-power electric plant to convert the energy of the moving air into electric current is not mastering nature. Nature is not changed or affected in any way by what he does. The forces of nature that are operating in his generator are the same forces that have been operating for millions of years. What has happened is that the engineer has learned the laws of nature and has arranged for them to operate under conditions that will produce an electric current and send it out on the wire.



Wincharger Corporation

An electric plant that transforms the energy of the wind into electricity and furnishes light and power to a country home. The makers of the plant did not change the laws of nature. They merely arranged for the natural forces about the homestead to operate under such conditions that an electric current is produced and sent down the wire.

Constancy of the living world. The biological world is also a world of laws. It is according to natural law for a person vaccinated with cowpox virus to develop a mild infection and become immune to It is natural for an unvacsmallpox. cinated person who gets the malignant type of smallpox germs in his system to develop so severe an infection that death often results. Nature is constant through both time and space. and in all cases in which nature is involved, without regard to our wills and wishes, that which is natural under any given set of conditions comes to pass. Two thousand years ago the poet Horace wrote, "You may throw nature out of doors with violence, but she will come back." "If you oppose nature she will destroy you" are the words of the great Pasteur.

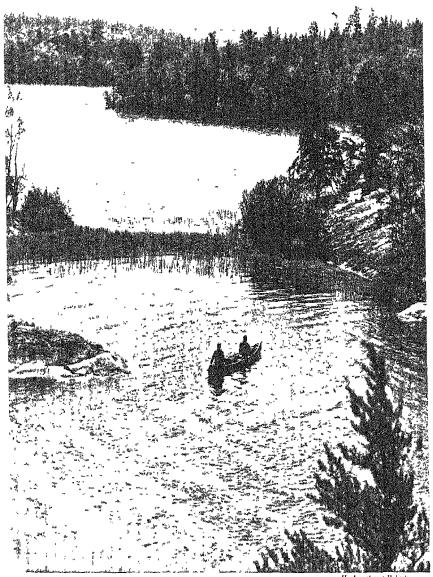
Mental adjustment to the world necessary. Mental as well as physical harmony with the world is necessary, for man's mind has not only made him supreme on the earth

but it has also made him much trouble. Many persons spend their lives in complaining and in futile rebellion against that which cannot be changed, while they fail to think and plan about what might be changed to make their situations more satisfactory. All about you are persons who get on smoothly and successfully and others of equal abilities who are continually in trouble. The difference is often a matter of mental adaptation to the world. One of the commonest failures of man is the failure to adjust himself to the conditions of life in a common-sense way.

How biology helps us in adjustment problems. Biology helps us in two ways in adjusting ourselves to the world. In the first place it helps us to understand the world and more than any other science it teaches us to understand ourselves. This helps us to see ourselves as we are — to perceive what we can and cannot do and to concentrate on what we can change and improve.

In the second place biology, like the other sciences, leads us to accept the world as it is and not to expect it to be changed for our particular benefit. It impresses on us that we can prosper only by falling in step with nature and going her way. We do not fight against gravity, because it is no use. We are resigned to the succession of the seasons because we know we cannot stop them. So when we understand the world and our own abilities we tend to give up impossible hopes and ambitions and to seek that which is possible for us.

An objective scientific attitude toward life and the world is a mental quality much to be desired; for to attempt to oppose or override nature is blind folly. The farmer should have crops that are adapted to his climate and soil. The statesman should plan for a government that is fitted to the nature of the people who will administer it and live under it. You should try to select a life work in accordance with your abilities and desires. The only wise course is to bow to nature's authority, learn her laws, and live in harmony with her decrees. An understanding of biology helps us to see this and to do the things that nature will approve.



H Armstrong Roberts

PROBLEM SIX

How Does the Study of Biology Aid in the Satisfaction of Our Instinctive Desires?

"There is a presence and an influence in Nature and the Open which expands the mind and causes brigand cares and worries to drop off — whereas in confined places foolish and futile thoughts of all kinds swarm like microbes and cloud and conceal the soul."

Lecture I, The Teaching of the Upanishads

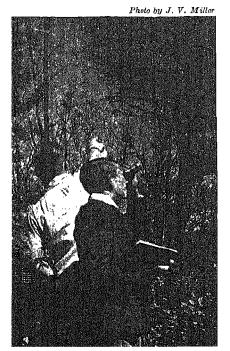
Have you walked through the woods in early spring and seen the white blossoms of the bloodroot pushing up among the leaves? Have you gathered the yellow jasmine of the South or have you come upon a bed of lupines spread like a purple carpet on the earth? Have you looked on a line of lacy dogwoods marking the course of a small stream or have you seen a mountain cove filled with wild azalea bloom? Have you watched the squirrels at play or waited for the whistle of a quail? None of these things did you any direct physical good. None of them exercised your intellect. Yet they gave deep satisfaction to a part of you.

Harmony with our instinctive nature necessary. Physical and mental adjustment to the world is necessary, but it is not enough; for man is more than a physical and mental being. From the instincts seated deep in his nature there arise desires that must be satisfied to prevent disturbances of the personality. Much of what we loosely speak of as neuroses and mental troubles are not troubles of the mind at all but rebellion against conditions of life that thwart instinctive desires. For the development and health of the full personality, conditions of life that harmonize with our innate natures are required.

In human beings there is an instinctive desire for contact with the world of living things. This is shown by the way men write poems about birds and trees and flowers; by the way they dig in gardens to see plants grow; by their keeping of animals as pets for the pleasure of associating with them; by their willingness to drive long distances to camp in forests; by the fact that living things arouse not only our intellectual interest but our emotions and sentiments as well. We have camps and public parks to help supply this contact with nature; the Scout and Woodcraft movements help furnish it for boys and girls.

Biology gives contact with living things. The study of biology leads into the great outdoors from which we sprang and to the world of nature of which we are a part. It takes us away from the cities and offices and factories and the rush of life generally which wears us and leaves us unsatisfied and disturbed. It gives opportunity to enjoy the quiet and beauty of nature and it heightens the attractiveness of living things for us by attaching an intellectual interest to them.

When we understand the processes that go on in a great tree we find nothing more wonderful than the way it spreads its leaves to the light and in silence and without moving from its place makes the food it needs for its life and growth. When we know



biology we look on the tiny plants clinging to trees and the little peoples of the grass and woods as living beings like ourselves. We are interested in how they meet their problems and we compare their lives with our own. We are then never in the condition of being unable to stay outdoors because "there is nothing to do," for an unending source of entertainment is about us at

Perhaps all the reason that need be given for the study of biology is that it leads us to the outdoors from whence we came and to the world of nature of which we are a part. all times. One of the most important reasons that can be given for the study of biology is that it introduces us to new outdoor fields of satisfaction and delight.

In this connection one of the old Greek myths is interesting, for in myths and legends we often find those things that people feel and believe but cannot prove. According to this legend Hercules wrestled Antaeus, son of Poseidon and Gea (Earth), and his great difficulty was in keeping his opponent down. When Antaeus was thrown it brought him into contact with his mother, Earth, and from her he drew new strength. At length Hercules, finding from whence the renewed power of his antagonist came, ended the contest by holding him aloft and crushing him in his arms.

So our modern life tends to crush us if we live it entirely in schoolrooms, factories, and offices and concern ourselves only with the affairs of man. We need contact with nature to renew our spiritual strength.

PROBLEM SEVEN

What Help Can Biology Give in the Solution of Our Social Problems?

"It has come to be recognized that man is a biological specimen, as much as are snakes and newts; his affairs are biological affairs and must be carried on in accordance with sound biological principles."

HERBERT S. JENNINGS

The most pressing problems of mankind are problems of group relationships. Nations threaten each other with war; persons of different occupations divide against each other in hostile array. Instead of peace and coöperation there is strife and confusion through much of the realm of human relationships. Man is a biological being and the trouble area lies in the life-science field. Has biology anything to offer that will aid in a solution of these problems?

Biology has no complete program of social reforms to offer, but it can present certain facts and principles that all who are concerned with human relationships should consider with the greatest care.

Biological point of view. A great educator has said: "The biologists are the only people who have a distinctive social point of view. They look at human beings and human affairs one way and the rest of the world sees them another way." What is this distinctive point of view that biologists have?

Many facts and ideas of biology influence our opinions on particular social questions, but what is called the biological point of view consists in large part in looking at man in much the same way as we regard other animals. The biologist knows that there is a relationship between man and other living things. The body of man is nourished as the bodies of other animals are. It is built on the same general plan as the bodies of the other vertebrates and develops in the same way. The same laws of inheritance that hold for other animals apply to man. Man has instincts and emotions that cause him to act in certain ways just

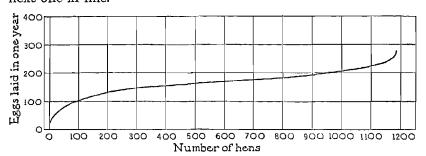
as other animals have. These and other facts cause the biologist to think of man not as a creature entirely apart from and above the other animals, but rather as a being with a wonderful intelligence added to his animal nature. We shall present a few facts in further explanation of why biologists hold to this point of view.

Taking account of man's original nature. Those in charge of our zoölogical gardens study the dispositions and behavior of the animals under their care and try to arrange conditions so that the various animals will be contented and will thrive. The monkey is given a place to climb. The badger is provided with a burrow. A flying cage is arranged for the birds. An attempt is made to allow a way of living to each animal that is in accord with its instincts and desires.

The biologist tends to carry this same point of view into his social and political thinking. He is inclined to study the nature of human beings and to take account of their likes and their dislikes and to try to plan a social order that will fit men as they are and not as they might be. He is inclined to read history as a record of how the human animal acts and he feels that what we need most to guide us in government is a scientific understanding of man himself. The biologist naturally feels that proposed changes in human relationships should be considered in the light of human nature before they are put into effect, for they must succeed or fail in accordance with the way people act under them. Biology tends to give this very practical (the only practical) social point of view.

Law of normal variation. Select a thousand men at random from a population that is all of one race and line the men up according to height. You will find that you have a few very short men and a few unusually tall ones. A line run over their heads will have the form of the curve in the graph on page 38. At first the curve rises quite rapidly until about 5 per cent have been passed over. Then it straightens and flattens, gradually rising until the last 5 per cent are reached. Here it again turns sharply upward. At either end are a few extremes, decidedly

shorter or taller than the average, and the nearer you are to the end the greater is the difference in the height of each man from the next one in line.



A graph of the yearly egg record of 1178 hens. It illustrates the law of normal variation. Note that a few hens had very low and a few very high records and that the records of the great middle group gradually grade upward from the lower to the higher extreme. (From data furnished by Professor C. S. Platt of the New Jersey State College of Agriculture.)

This law of variation holds not only for the height of human beings but for any other human quality we may select. It holds for weight, for intelligence, for industry, for unselfishness, for honesty. It holds not only for men but for animals that are bred without scientific selection as men are. Examine the egg record of a thousand hens, the milk record of a thousand cows, the weights or lengths of a thousand ears of corn, and the curve is the same. There are a few extremes far above or below the average and a great middle section gradually grading upward from the lower extreme. Plot your figures as a graph and you will have the curve shown in the illustration. It is called the curve of normal variation. Of the law of normal variation which the curve represents Sir Francis Galton, an English scientist, wrote:

"It reigns with serenity in ample self-inforcement amidst the wildest confusion. The larger the mob and the greater the apparent anarchy, the more perfect is its sway. It is the supreme law of Unreason. Wherever a large sample of chaotic elements are taken in hand and marshaled in the order of their magnitude, an unsuspected and most beautiful form of regularity proves it to have been latent all along."

Biology and a world of differences. In accordance with the law of normal variation, a biologist expects to find natural differences in people. He is prepared to find great differences in mechanical, artistic, and intellectual ability. He expects to find that men differ naturally in cruelty, sympathy, honesty, selfishness, self-control, energy, ambition, desire for power, and all other human qualities, good or bad. He knows that by training much can be done to develop abilities and to change behavior, but always he has in mind that there are innate differences in persons that cannot be removed. Many human characters and qualities are independent of each other and the relative standing of persons would be different according to the character for which they were ranked. In any one character we may select, however, there is variation according to the law described above.

Further, the biologist knows that the offering of better opportunities to all results only in greater differences. If musical training is given to a group the more gifted and interested individuals will profit most and will be farther ahead of the less talented after the training than before. If arithmetic is taught in a school certain individuals with natural aptitude for numbers will learn most rapidly: the differences in the ability of the more gifted and of the slower-learning pupils to use numbers will be increased. Similarly, under good economic opportunities, if freedom is allowed, the difference between the top and the bottom is far greater than under hard conditions. Improvement in economic conditions raises the living standards of the less able and industrious members of the social group, but if freedom is allowed it raises the standards of the abler and harder-working members still more. It is opportunity that allows an individual to take advantage of the natural abilities he has. Those with the best abilities profit most by opportunity.

It is hard for many persons to become reconciled to these differences among human beings and to the social and economic difficulties rising out of them. The biologist is no oracle with ready solutions of all our social questions, but he does appreciate that there are natural differences in persons and he understands that

the giving of freedom for the development and use of abilities magnifies the differences. He knows that no matter how society is organized, to secure equality of accomplishment in any field of endeavor "the more efficient must be shackled that they may not outrun the less efficient." It is natural for the biologist to expect different persons to excel in different abilities, some in one and some in another, and to look for abilities of various kinds that can be developed and used. In general, an understanding of biology prepares for living more comprehendingly in the world of natural inequalities that we have and will have until all persons are born alike.

Need for extension of human biology. We should use the scientific method in our study of all the affairs of man. We are for the first time in the history of the world able to produce enough food, fuel, clothing, and shelter to give all members of a human group a comfortable living. We still have poverty among us because we are able only in part to use our scientific knowledge and production abilities for the good of man. What we have as yet failed to do is to make a scientific analysis of human nature and to find solutions for the problems of human relationships. The consequent lack of harmony and peace among men keeps from us the abundant life that science has placed within our reach. Evidently much is wrong in our social world and when we ask what it is and why and what can be done to remedy the situation we find that we need someone who can speak with the authority that knowledge gives.

Science has a proved and tested method of finding knowledge and this method should be used to gain the information that we need for the handling of our social problems. It is the slow, hard, patient way of going at them, but it is evident that they are too complex to be solved by guesswork or by the hit-or-miss methods that up to now have been applied to them. The mainsprings of human behavior must be ferreted out. The conduct of groups of men as well as of individual men must be analyzed. We must develop sociologists and psychologists and statesmen who know their human material in the same way that the construction

engineer knows steel. The greatest need of the world is that human biology shall be pressed forward until man and his ways are understood. If you want a "practical" field of biology in which to work, it is here.

The airplane is used for the slaughter of innocent persons. The radio is employed to bring whole nations into mental enslavement. May it not be that too great an advance in science is evil rather than good? What shall we reply to those who ask this question?

The reply is that science in itself is neither good nor evil. The morality or immorality is in those who use it. A man can do a good or an evil deed with his hands. He can use fire to keep himself warm or to burn his neighbor's home. Any power whatsoever that man has over physical nature can be used either to the benefit or the hurt of mankind. Our trouble is not in having scientists who can build airplanes but in the lack of scientists in the field of human relationships to direct their use.

The remedy, as we have indicated, is in the development of a true science of human nature and of social organization. We must have knowledge that will enable our political and spiritual leaders to go forward with the same confidence now displayed by the leaders in scientific fields. We must have proved standards for the judging of men that will identify demagogues and adventurers and keep them from reaching positions of power. By the use of the method of science we have learned the secrets of the distant stars and the changes the earth has undergone in ages long past. Our need is to apply this great instrumentality to the building of a social order in which men of good will and intelligence will control and in which justice and peace will prevail. Not less science, but more and in new fields, is the hope of mankind.

THE CONCLUSION OF THE MATTER

"Never, no never, did nature say one thing and wisdom another." EDMUND BURKE

Science has been defined as organized knowledge — a collection of facts set in order so that their meaning will appear. It has been defined as a method of working and thinking by which facts are collected and ideas and theories checked by them. It has been identified as the spirit that seeks truth and is willing to abide by truth. It is all of these things. Science is an organized method of applying the intellect to human affairs. Its conscious purpose is to bring intelligence to bear on the solution of the problems of mankind.

In this great endeavor biology must play its part and although it is a young science it can have very great values for you. It can show you the method of science and reveal the scientific mentality. In regard to your physical being it can give you information of great practical value. It can help you harmonize yourself with the world in which you live, which you must do if your life is to be a success. It can give you a valuable social point of view. Concerning the instinctive, emotional, and mental nature of man we have as yet comparatively little tested and proved knowledge, but psychology is marching on and a grounding in fundamental biology will help you follow its course. The intelligence of man must be focused on man himself until his motives and desires are understood and a political and social system arranged that will develop what is best in him.

Possibly, too, somewhere in the wide field of biology you may find a life work that will be satisfactory to you and beneficial to mankind, for in the near future we shall see unusually great advances in the life sciences. New discoveries in chemistry and physics have given us new ways of studying living things. New fields of biology are being opened that will yield rich harvests to the workers in them. No field of science is more inviting than is biology today. There are many reasons for studying biology. An especially good time to study biology is now.

UNIT COMPREHENSION TEST

- A. What is the essential feature of the scientific method? What is a hypothesis? Why must fact finding always be an indispensable part of the scientific method? What are two methods of collecting facts? What evidence is there that the scientific method is the fruitful way? What does the word "science" mean? Is there any reason why science should be limited to any particular fields?
- B. What are the characteristics of the scientific mind? Why, when scientists are so cautious, does science progress so rapidly? What advantage is there to a person in having a scientific outlook on the world and a scientific attitude of mind? What is the best method of acquiring the scientific mind?
- C. Why does mankind so easily fall into superstitions and become a victim of misleading propaganda? What is witchcraft? How long since a belief in it disappeared among the educated classes of Europe and America? What is astrology? What evidence is there that a belief in it is still widely held and what harm results from this belief? How does science destroy superstition? How does science serve as a safeguard against misleading propaganda? Why is the mission of science as a mental liberator so important?
- D. What are some ways in which science has helped to control disease? What was Malthus' theory? Why does this theory not hold in countries like our own today? Name at least four ways in which science has increased our food supply. Mention some ways by which the food supply of the future may be increased. Give an important reason for placing biology in the school course.
- E. In what sense can we master nature? Why is mental adjustment to the world necessary? How does biology help us to make this adjustment? What did Pasteur mean when he said, "If you oppose nature, she will destroy you"?
- F. Why is it important that man's innate needs be satisfied? What are some of man's activities that indicate an instinctive desire for contact with nature? How does biology encourage and help in securing this contact? Relate the legend of the contest between Hercules and Antaeus,
- G. What is meant by the biological point of view in human affairs? What is meant by the law of normal variation? How does an understanding of this law give a better insight into human nature and human problems? Why does not the granting of equal opportunities to all remove inequalities among people? Why is it important that the scientific method be employed in the solution of problems of human relationships?

SUGGESTED ACTIVITIES AND APPLICATIONS

- 1. Carry out the experiments and make the observations indicated in the text of this unit.
- 2. It is said that in the northern hemisphere trees twist only in a counterclockwise direction. Determine by observation whether this statement is correct. (As applied to the twisting of a tree, "clockwise" means the direction the hands of a clock move when the clock is laid face up.)
- 3. By observation gain the information to answer the following questions: (a) How many legs has an insect? (b) How many legs has a spider? (c) How does ivy cling to a wall?
 - 4. Class project:

Gather from one tree a quantity of leaves selected at random-Oak, peach, maple, or any other leaves of fair size will do. Beech leaves hold their shape when dry and a basketful of these collected after they have fallen makes good material with which to work.

Working in pairs, one measuring and one recording the measurements, let the members of the class measure the length of several hundred (better a thousand or more) leaves to the nearest quarter of an inch. (If centimeter rules are available, the measurements may be made in half centimeters.) As the leaves are measured, lay them in separate piles according to their lengths.

Collect the results of all the measurements, add them together, and find the number of leaves of each length. Draw a chart similar to the one on page 38, with the horizontal axis labeled "Number of leaves" and the vertical one "Quarter inches" (or "Half centimeters"). The height of the chart may vary according to the length of the leaves used.

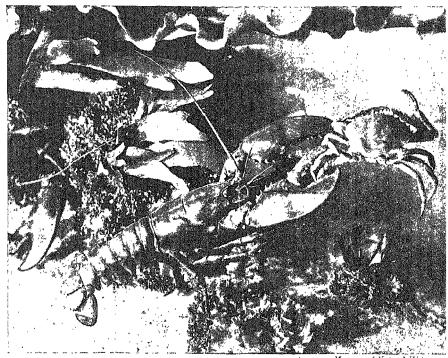
On the chart plot the results of the measurements as a graph. Do the results confirm the law of normal variation?

5. If all the boys (or all the girls) of the same age in your school were arranged according to height, would they follow the law of normal variation? If they were arranged according to weight, according to their school grades, according to their musical ability, or according to their speed in running, would the law be observed?

Would the order of the students be different in each of these arrangements?

Are persons always or usually interested along the lines of their greatest abilities?

Do you think that it is possible for you to increase your chance of success by an open-minded consideration of your own abilities?



American Museum of Natural History

unit 2

THE DIVERSITY OF LIFE

In the realm of life there is an infinite diversity.

[&]quot;What a gamut of life from the microscopic infusorian to the giant whale, from the hyssop on the wall to the cedar of Lebanon! . . . What variety of architecture, what abundance of individuality!" J. ARTHUR THOMSON

THE VARIETY OF LIVING THINGS

QUESTION FOR CLASS DISCUSSION

Why do the plants that men cultivate and the animals that they keep differ in different parts of the earth?

WHEN we turn our attention to the materials that we are to study in our life science course we are amazed at their abundance and diversity. More than 800,000 different kinds of living animals have been described and classified and it is estimated that there are as many more that have not yet been named. In size, in form, and in appearance they are as diverse as could well be imagined. Their habitats range from bleak mountain tops to the bottoms of the lowest ocean deeps and the differences in their ways of life are extreme. It would seem that nature had extended her imagination to the utmost and employed all her ingenuity in creating as many different kinds of animals as possible and in fitting animals for life in almost every niche and corner of the earth.

Nor are the plants less varied. In number of kinds they run into the hundreds of thousands. In size they range from tiny bacteria up to giant sequoias that weigh more than two million pounds. Like the animals, they live on land and in the sea, in the tropics, and on the tundras of the far north. In form, in structure, and in their adaptations to different life conditions, plants exhibit a diversity that the human imagination could never have conceived. In biology we have for our study such a profusion of materials as no other science knows.

The general theme of this unit is the diversity found among living things. One purpose of the unit is to explain the system that scientists use in classifying and naming the almost endless variety of organisms (living things) with which they deal and to list and describe briefly the chief animal and plant groups. A second purpose is to set forth the theory that biologists hold as

to how the many different kinds of living things originated and became adapted to their environments and ways of living. In our study we shall try to find an explanation of why there are so many different kinds of living things on the earth and why they differ so greatly.

In the unit the races of men are briefly considered because these races are a familiar illustration of the results of variation in a single animal stock and because you must include man in your studies if in your social thinking you are to develop the biological point of view.

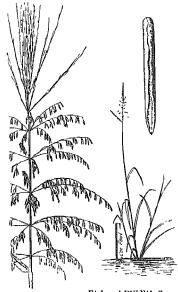
Problems in Unit 2

- 1 What system is used in naming and classifying plants and animals?
- 2 What are the chief groups of the animal and the plant kingdoms?
- 3 What are the principal races of mankind?
- 4 How and when did the primary races of mankind originate?
- 5 What are the principal branches of the Caucasian race?
- 6 How can we account for the great number of different kinds of plants and animals on the earth?

PROBLEM ONE

What System Is Used in Naming and Classifying Plants and Animals?

The word "gopher" in the Dakotas means a large field mouse and in Florida a burrowing tortoise. "Honeysuckle" in different parts of our country may mean a bush, a vine, or an herb with blue flowers. In England one kind of violet has thirty-seven common names and digitalis has seventy-one. The common



Fish and Wildlife Service

A species of wild rice that grows over a great part of temperate North America and also in China and Japan. It has at least sixty common names in the United States alone. The scientific name Zizania aquatica identifies it everywhere.

names of plants and animals may be utterly confusing outside very restricted localities because often people call different kinds by the same name and give to a single kind many different names. Scientists working in different countries or even in a single country cannot tell from a common name what plant or animal is meant.

To meet this situation, biologists have devised a scientific system for classifying and naming plants and animals that identifies each particular kind. By this system the plants and animals are arranged in groups and subgroups according to their relationships. Then each kind is given a particular name, and with the name and classification there is provided a careful description of the plant or animal

that will distinguish it from other kinds. By the use of this system it is possible for any scientist, no matter where he lives or what language he uses, to know from the name the exact plant

or animal to which the name applies. The same scientific names are used in all countries; so in these names biologists have a universal language that all understand.

Classification and naming system. In the scientific classifying and naming system the first division of living things is into the plant and animal kingdoms. Then each kingdom is divided into great groups that are called phyla (fī'la; singular phylum). The phyla are divided into classes, the classes into orders, the orders into families, the families into genera (jĕn'er-a; singular genus, jē'nus). Finally the genera are divided into species (spē'shēz), or individual kinds, and each species is given a particular name. Sometimes subdivisions of a group are made, as subphyla and subclasses, and if there is much variation in a species it may be divided into subspecies or varieties.

Here is the full classification scheme:

Kingdom

Phylum

Class

Order

Family

Genus

Species

Variety

The name given to each species is a double one. For example, Canis lupus is the name of the European wolf and Canis familiaris of the domestic dog. The first part of the name (Canis) is that of the genus and the second part (lupus or familiaris) is the particular name of the species. As all the members of a human family have one name in common and each one has a name that belongs particularly to him, so all the members of a genus have the same name and each species adds a name of its own.

Using the classification and naming scheme. The scientific classification and naming of the dromedary, or Arabian camel, will illustrate how the system is used. The dromedary belongs to the animal kingdom and, because it has a backbone, to the Subphylum Vertebrata. It feeds its young on

milk and has hair on its body; therefore it is a mammal and belongs in the Class Mammalia. It is one of the hoofed mammals and has an even number of toes; therefore its place is in the Order Artiodactyla (ar'tĭ-o-dăk'tĭ-la). It has no horns, certain peculiarities of the teeth, and on the feet thickened pads of skin which enclose the toes. These characteristics place it in the Family Camellidae (ka-mĕl'ĭ-dē). It has a fleshy hump on its back, a long curved neck, and water pouches formed by infoldings of the stomach walls, which makes it a member of the Genus Camelus (ka-mē'lus). It has only one hump and it is therefore Camelus dromedarius.

The other species in the genus is the two-humped camel, *Camelus bactrianus*, of central Asia. Both members of the genus have the same first (generic) name and each has a second (specific) name of its own. Note that the generic name begins with a capital letter and the specific name with a small letter and that both names are in italics.

A difficulty in writing generic names. Confusion as to the proper way to write generic names may arise when they are used also as common names. Familiar examples of generic plant names that are thus employed are Anemone, Azalea, Clematis, Hudrangea, Petunia, Cosmos, Magnolia, and Rhododendron. These are scientific names of plant genera and they are also the common names of garden plants. When we are using such terms in a strictly scientific way to identify a genus or a species, we italicize and capitalize. In books such as this, however, where a generic name is used repeatedly in referring to an organism or a group, it is customary to write it as we do any proper name with a capital and without italics. Also, where generic names are in use as familiar common names, often both the capital and italics are dropped. A person writing about the clematis on the porch and the cosmos in the garden writes "clematis" and "cosmos" as common names. In this book a generic name is italicized and capitalized the first time it is introduced, to show that it is a scientific name. Afterward it is usually treated as a proper or a common name.

The species description. The scientist who names a species also writes the description of the species that gives the distinguishing characteristics of the particular kind of plant or animal to which the name is given. Thus if you were to look up the classification of the wild prairie rose of North America you would find it under the scientific name Rosa setigera (sĕ-tĭj'er-a), with a description somewhat like this:

"The only American wild rose with climbing stems. Prickles sharp and stout; shoots may grow 10 to 20 feet in a season. Forms dense clumps on the borders of prairies or thickets. Found from Ontario to Ohio, South Carolina, and Florida, and west to Wisconsin, Nebraska, and Texas."

This description will distinguish the prairie rose not only from the dwarf wild rose, the Cherokee rose of the South, and any of the other American wild roses, but also from the English eglantine, or sweetbrier, which in some places has run wild in our country.

Structure the basis of classification. The object in scientific classification is to arrange plants and animals in groups according to their natural relationships. When this has been done we have the great advantage of being able to study them by groups instead of by individual kinds. In classifying bacteria and other small forms we often judge of their relationships by their ability to cause chemical change or to cause disease, and in the classification of the larger plants and animals we are beginning to use chemical tests such as blood tests to determine which ones are closely related and which are not. In the main, however, we classify the higher plants and animals in accordance with the structures that we find in them. We place those with the same structures together because we believe that the structures show relationships.

Thus all the animals with backbones we class as vertebrates. All with feathers we call birds. Those with hair and glands that secrete milk for the nourishment of the young we place together as mammals. In plants the flowers and fruits and in animals the



Dryobates villosus

Dryobates villosus. Hairy woodpecker. Big Sapsucker. Spotted and lengthwise streaked, but not banded; back black with a long white stripe; outer tail feathers wholly white. Scarlet band on back of head of male. Length, 9 inches.

Northeastern United States and Canada; west to Colorado. Several sub-species in west. Southern race smaller.



Dryobates pubescens

Dryobates pubescens. Downy woodpecker. Little Sapsucker. Outer tail feathers barred with black; otherwise like above species but much smaller. 6½ inches long. Many sub-species and varieties.

Eastern United States and north to Newfoundland.



Dryobates borealis. Red-cockaded woodpecker. Black and white, spotted below and cross-banded above, but not streaked lengthwise. Back black, barred with white. A red line on each side of head in male. Length, 8½ inches.

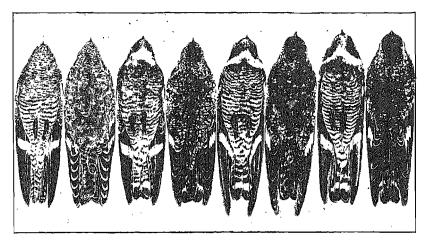
North to New Jersey in woodlands.

Dryobates borealis

Three species of woodpeckers. All of them have the same generic name and each has a specific name of its own.

main body parts are the structures that are the most reliable guides in classification. The stems and leaves of plants and the limbs of animals are not so reliable as guides. They are likely to vary greatly because of adaptation to living conditions and modes of life.

A difficulty in classification. When a person begins classifying plants and animals his great difficulty is that often he finds no sharp lines marking off species and groups. Rather does he find in his materials all kinds of differences both great and small and it is in many cases difficult to decide how important he shall consider the differences to be. If you were asked to separate apples as they come from a tree into groups according to their size you would have to decide how many groups you would make and then you might find it difficult to decide where to place some of the apples. There would be no particular places at which the size of the apples changed abruptly; so you would be compelled to use your own judgment about how many classes you would make. Similarly each person who classifies new plants or animals must use his judgment about how many



A back and breast view of four nighthawks, showing variation in their plumage. Suppose we consider that the one on the right and the one on the left belong to different species or sub-species. How, then, shall we classify the two that are between them? (From Birds of Minnesota: Vol. II, published by University of Minnesota Press.)



Pictures, Inc.

A young tiglon. It is a hybrid between two distinct species. The father was a Siberian tiger and the mother a lioness.

species he will make and into what larger groups he will arrange the species.

For a time a species was defined as a kind of plant or animal that would not interbreed with any other kind, but this definition had to be given up. lion will cross (hybridize) with the tiger, the ass and zebra with the horse, the American bison with domestic cattle, the pheasant with the hen, the radish with the cabbage, and the raspberry with the dewberry. In each of these cases the kinds of animals or plants are so far apart that they seem clearly to belong to different species

and yet they do hybridize; therefore this test of a species is not valid. Neither is any other test of a species always valid; nor can we say what shall be considered to be the differences between genera or other larger groups. All who classify plants and animals recognize that whether differences shall be considered as indicating a family, a genus, or a species is often a matter of judgment. The hard-and-fast lines that we draw in our classification scheme are not in the plants and animals themselves.

The father of the double-naming system. The scientific system of naming plants and animals was devised by a Swedish biologist called Carolus Linnaeus (lǐ-nē'us). His real name was Carl von Linné, but he used the Latin form (Carolus Linnaeus) because Latin was the scientific language of his age and all his scientific writing was done in it.

Linnaeus was born in 1707. His father was a country minister who wished his son to become a minister also. Young Carl's interest, however, was not in Hebrew and theology but in nature and especially in plants. He examined all the plants he could find and learned their names, and while yet an undergraduate at the University of Upsala he obtained permission to give lectures in botany. He received the fees the students paid for these lectures and thought that his financial problems had been solved, when an unexpected difficulty arose. So great was his enthusiasm and so interesting were his classes that he drew the students away from the regular courses in botany and permission to give the lectures was withdrawn.

Intelligent, strong, and active, Linnaeus was ready for other work. He was asked by the Swedish government to go to Lapland and make a report on its plants and its economic resources. He



Carolus Linnaeus, the father of the double-naming system. He did the world a great service when he devised a system of naming plants and animals that enables scientists in all lands to know the exact plant or animal to which a name applies.

accepted with joy this opportunity to study plants he had not seen and to classify them. The following extract from his diary shows the enthusiasm with which he set forth:

"I journeyed from Upsala town the 12th of May, 1732, which was a Friday, 11 A.M., when I was twenty-five years old, all but twelve hours. Now began all the ground to delight and smile, - now stood forth the winter rye a quarter of an ell tall, and the grain had newly shown a The birch began now to burst forth, and all leafy trees to show their leaves except the elm and aspen. . . . The lark sang to us the whole way, quivering in the air. . . . The sky was clear and warm, the west wind cooled with a pleasant breeze. . . . The woods began to increase more and more, the sweet lark which ere now had delighted our ears, deserted us; but yet another one meets us in the woods with as great a compliment, namely the thrush, Turdus minor, who when she on the highest fir top plays to her dearest, also lets us joy therein. Yes, she tunes in so high with her varied notes that she often overmasters the nightingale, the master of song."

During the long days of the Lapland summer Linnaeus journeyed on, most of the time on foot and much of the time alone. He covered 2500 miles, and in the autumn returned laden with



specimens of new plants. Later he became professor of botany at the University of Upsala and by his love of plants and by his enthusiasm and kindliness he made friends all over the world. From the most distant parts of the earth people sent or brought

The mountain laurel or calico bush, Kalmia latifolia. It is one of the many American plants sent to Linnaeus and classified and named by him. specimens of plants to him and he named and classified them all. Do you know the mountain laurel? Its scientific name is *Kalmia latifolia*. A specimen was sent to Linnaeus from America by Peter Kalm and in honor of the sender it was named *Kalmia*. It is only one of many American plants that Linnaeus named.

Classifying and naming plants and animals is only a small part of biology, but it is a necessary part; and Linnaeus did the world a great service when he devised a system of naming that works so well. In classifying organisms we not only learn their names but find out which ones are related and just what are the differences between groups. Many famous biologists have begun their studies of living things by collecting and classifying the plant or animal forms about them.

PROBLEM TWO

What Are the Chief Groups of the Animal and the Plant Kingdoms?

In the Appendix of this book the principal animal and plant phyla and some of the subdivisions of the more important phyla are listed (pages 987 to 997). To begin your attack on the present problem, turn to that list and read carefully through the outline classification. As you read, examine the accompanying illustrations and note the characteristics of the groups. Study also the meanings and derivations of the scientific names, for many of them are descriptive of the groups. Do not try to commit to memory the list of groups.

The purpose of this study is to help you to become familiar with the classification of plants and animals in a very general way, so that when a form is mentioned you will have some idea of what it is like. It will be a very profitable activity for the members of the class to bring in plant and animal specimens and arrange them in accordance with their scientific groupings. Clipping pictures of animals from magazines and newspapers and arranging them according to the relationships of the animals will give additional interesting practice in classification. If you get a general idea of the main plant and animal groups you can then as the course proceeds fit into the classification scheme the different forms that are taken up for study. The classification outline has been placed at the back of the book so that it will be convenient for constant reference.

Possibly you may become interested in learning the classification and scientific names of the individual species of butterflies, frogs, reptiles, birds, ferns, trees, or flowers of your region. For this work special books on the different groups are required, and numerous excellent books designed to help the beginner in classification have been prepared. Many of the groups listed in the Appendix of this book are described more fully in the text. Page references to these descriptions will be found in the Index.

PROBLEM THREE

What Are the Principal Races of Mankind?

Man varies as other animals do; there are many types, or races, of men with differences between them that are well marked and consistently inherited. The differences are not great enough, however, to cause the different kinds of living men to be classified as separate species. What we call races of man correspond to varieties of plants or to breeds of domestic animals. All the living races of man are placed in one species, *Homo sapiens*.

Classification characteristics. Characteristics that are given much prominence in human classification are hair character (straight, wavy, curly), the shape of the head, and the shape of the nose. Great attention is given to the bony structures not only of the head but of other parts of the body, for human skeletons of earlier races have been preserved and it is possible to compare them with those of present-day men. The amount of face and body hair is also important as an indicator of race; some peoples have heavy beards and hairy bodies while others have almost no hair except on the head. Skin color crosses race lines and is an unreliable guide to relationships; there are branches of all races that have developed dark skins. Language and nationality do not count in human classification, for people can learn any language, and race is a matter of biological kinship and not of place of residence.

THE GREAT DIVISIONS OF MANKIND

Man more than any other animal migrates and travels about, and all human races interbreed. This causes pure race types to be the exception and complex hybrids to be the rule. For this reason no animal is harder than man to classify, and there is no universally accepted scheme of classification. We shall, without explanation of the reasons for selecting it, use the scheme indicated in the table on page 61. According to it there are four primary races: the Caucasian, Australoid, Negroid or woolly-

haired, and Yellow-brown or Mongoloid. Doubtless it will be helpful if you consult this table as the study of the problem proceeds.

The Caucasian race. The Caucasian race has straight or wavy hair and more hair on the face and body than any other race except the Australian. In the Old World it is found in Europe, northern and eastern Africa, western Asia, and northern India. The Arabs, the peoples of northern Africa and Egypt, and the Afghans and some Hindus are non-European peoples of the Caucasian race. The two divisions of the race are the Hyperboreans and the Mediterraneans.

The Hyperboreans are peoples of large size who have a tendency to develop bony ridges over the eyes and to resemble in their physical traits in general the old hunters who inhabited northern Africa, Europe, and northern Asia during the last ice age. The Mediterraneans are more slender and are supposedly descended from an agricultural people that arose in Egypt or western Asia and from there has spread over a great part of the earth.

The Australoid race. The Australoids are the remnant of a people that once occupied most of southern Asia and the islands south to Australia and Tasmania. In them the skin color is deep brown or black, the nose is wide and flattish, the hair is wavy or ringlet curled. The beard is heavy and the body hairy. Some of them are even hairier than Europeans to whom this race seems distantly related. The two divisions of the race are the Veddoids (Věďoids) and the aboriginal Australians.

- (1) The Veddoids. The Veddoids are found as a pure race only in certain primitive tribes of Ceylon, Celebes, Sumatra, and other eastern tropical regions. They are, however, the main element in the population of southern India; there is a Veddoid strain in the peoples of Baluchistan and southern Arabia; and there is Veddoid blood in many of the peoples of the Melanesian isles. The Veddoids are a rather small people. In color they are a deep black.
- (2) The Australians. There are several sub-types of the Australian aborigines. They vary in stature and body build, but

PRINCIPAL RACES OF MANKIND

I. Primary races

- 1. Caucasian race
 - a. Hyperborean
 b. Mediterranean
- c. Sub-races of mixed Hyperborean and Mediterranean descent
- 2. Australoid race
 - a. Veddoid (Australoids who live outside Australia)
 - b. Aboriginal Australian
- 3. Negroid race
 - a. Negrito or Pygmy
 - b. Bushman-Hottentot
- c. African Negro
- d. Oceanic Negroid

- 4. Mongoloid race
 - a. Tungusic Peoples of eastern Siberia
 - Buryat-Mongol Peoples of Mongolia and Asiatic highlands north of the Himalayas
 - c. Sinitic Chinese
 - d. Malay

II. Secondary races

Mixed peoples formed by fusion of two or more of the primary races. Examples are American Indians, peoples of Turkestan and western Siberia, Polynesians.





lton S. Coon Peabody Museum, Harvard University

Representatives of the Australoid race. To the left is a Veddoid and at the right an aboriginal Australian.

they are in general somewhat taller than the Veddoids. In some of the sub-races there is a tendency to the development of over-hanging bony brow ridges as in the Hyperborean whites. The native Australians build no permanent houses and carry on no agriculture. They move about in small bands, living on what they can find from day to day. There are several thousands of these bands, each living independently and making its own laws.

The Negroid race. In this race are included the peoples that have the combination of flat noses and frizzly hair. Probably some of them are only distantly related to each other. Little is known of their ancestry or their relationships in ancient time. The chief divisions of the race are as follows:

(1) Negritos or Pygmies. The Negritos are the world's smallest people, being not much over 4 feet in height. They are forest dwellers and subsist by hunting. Tribes of them live in the African Congo, on the Andaman Islands in the Bay of Bengal, in the Malay Peninsula, and in the mountains of the Philip-

James Sawders

pines and New Guinea.

The Negritos show what biologists call discontinuous distribution, which means that they are found in widely separated areas and not between these areas. This is interpreted as meaning that they are an ancient people who were at one time widely distributed and have now died out as a pure race

Pygmies in the Malay Peninsula. These little people are found in widely scattered areas over much of the eastern tropics. The ones shown here are starting a fire by sawing a strip of rattan back and forth around a piece of dry wood.

except in a few scattered spots. An additional reason for holding this belief is that traces of Negrito blood are found over a wide region. Some of the inhabitants of southern India show Negrito traits; the Negrito stock is an important element in the composition of the Oceanic Negroids (Melanesians); and some of the aboriginal tribes in the rain forests of northeastern Australia are part Negrito. Where the Negritos originated and how they reached their present homes are unsolved mysteries.

All known evidence indicates that they are an extremely ancient people.

(2) Bushman-Hottentot. The Bushmen are a yellowish people of low stature (about 5 feet) that were formerly found over most of South Africa but now are confined chiefly to the region of the Kalahari Desert. In them. the hair is short and becomes rolled up in small knots so that it appears to grow in patches. The head is small and the face is flattish. The nose is extremely flat and often there is no lobe at the lower part of the ear. The hands and feet are small.



Peabody Museum, Harvard University
A Negro woman of West African
parentage. The photograph was
taken in South Carolina in 1865.

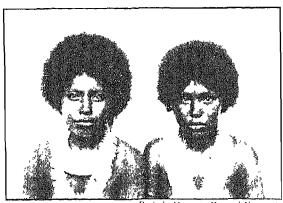
The Hottentots of southwest Africa are Bushmen modified by a strain of East African white blood. They have many features of the Bushmen but are about 3 inches taller. The Hottentots are keepers of cattle and live less primitively than the Bushmen.

(3) The African Negroes. The Negro's ancestral home is the part of the Sudan between the Sahara Desert on the north and the African equatorial forests to the south. From this region the Negroes have spread into the forest lands of the Pygmies and in the last few centuries down eastern Africa to the south. Within the Negro group various sub-races are found.

The West Coast Negroes are of only moderate height. They are dark brown or black. The shoulders are heavy and the arms are often long. Most American Negroes are of this strong and rather heavily built type.

The eastern Sudanese Negroes are narrow in the hips and shoulders, have longer legs, and are more slender in build. They average about 2 inches taller than their western relatives. They are also darker in color and in them the nose is flatter. They live in the eastern Sudan and the Upper Nile Valley. Some American Negroes are of this type.

Besides these two principal Negro varieties, there are, especially in East Africa, many tribes and nations of Negroes who have been modified by the admixture of Mediterranean white blood. In general, these East African Negroes are known as Bantus. The Zulus and Masai are examples of such tribes. They build vil-



Prabody Museum Harvard University

Two Melanesian girls. The Melanesians, or Oceanic Negroids, inhabit New Guinea and the Islands to the south and southeast. They have frizzly hair and dark skins, but they are not closely related to the African Negroes.

lages and carry on an advanced agricultural and industrial life. In color many of them are brown rather than black.

(4) Oceanic Negroids. The native peoples of New Guinea, of the many islands lying to the east and southeast of New Guinea

(Melanesian islands), and of Tasmania are black and have flat noses and woolly hair. They are classed as Negroids, but many of them are in part of Negrito and Australoid stock and in some of them there is evidence of Caucasian and Mongoloid mixtures. They are not closely related to the true Negroes of Africa.





Peabody Museum, Harvard University

Brown Brothers

A Tungusic (left), one of the northeastern Mongoloids. The Tungusics have light skins, long heads, and narrow faces. The Manchus who invaded China from the north were of this race. They are larger in body than the average of the Chinese.

A Chinese (right), representative of the Sinitic or central group of the Mongoloids. There is great variation in the members of this group. Those toward the south are smaller and have rounder heads and faces than the northern Chinese.

The Mongoloid race. The Mongoloid peoples occupy nearly all of eastern Asia and form one of the great divisions of mankind. In them the skin color varies from brunet white to dark brown, with often a yellowish tinge. The hair is coarse, straight, and black and is scanty on the face and body. The faces are usually flat and the cheekbones wide. Often there is a fold of skin across the inner corner of the eye which gives the eyes a slanting appearance. The different divisions of the race show great variations in body size and in the shape of the head. The four main divisions of the Mongoloids are indicated below.

(1) Tungusics. Many of the Tungusics of eastern Siberia are of a special Mongoloid type. They are of medium height and light-skinned. They have heads of long, low form, with sloping foreheads, and many of them have bony brow ridges. The



James Sawders



Peabody Museum, Harvard University

A Buryat-Mongol (above), an inhabitant of Mongolia. These northwestern Mongoloids are darker-skinned, stockier-built, and wider-faced than the Tungusics who live to the northeast of them. They are quite distinct from the Chinese.

To the left is a Malayan of the Dutch East Indies. The Malays are the southern branch of the Mongoloids. They are a small brown people with round heads

and round faces. They often lack the eyefold which gives the slanteyed appearance characteristic of other Mongoloids.

Manchus who pressed into China from the north are of this race, as were the ancient Huns who invaded Europe under Attila.

- (2) The Chinese proper. The Sinitic or Chinese Mongoloids have a light-yellowish skin. They are more slightly built than the Tungusics described above. Many of them are long-headed and narrow-faced. In southern China the people are smaller and the head and face tend more to roundness. This is the most numerous of all the branches of the Mongoloid race.
- (3) Buryat-Mongols. The Buryat (Boō'rĭ-ăt)-Mongols are larger than the Chinese and stockier than the Tungusics. They have

round heads and wide faces. They are dark-skinned and often have prominent noses. They inhabit Mongolia to the north and northwest of China and the type is often found also in Tibet. Genghis Khan and his followers were of this race. The tribes of western Siberia and of the regions north and northeast of the Caspian Sea are in part of Buryat-Mongol stock.

(4) Malays. The Malays are a southern division of the Mongoloid family. They are found in Burma, Siam, French Indo-China, the East Indies, and the Philippines. They often lack the eyefold characteristic of most other Mongols. The Malays are an alert, active people whose blood is widely spread through tropical Asia and the islands to the south and east.

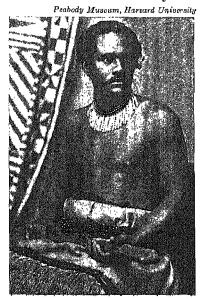
SECONDARY RACES

When a race is isolated it tends to become more uniform. Gradually the individuals of the race come to be more or less of one type, and we speak of them as making up a "pure" race. If, however, a people is brought into contact with other peoples of different types there is a mixing of the stocks. At first a mixed race results, but in time the diverse elements may be-

come thoroughly blended and a more or less uniform new race arise. The peoples briefly described below are important examples of races formed by combinations of elements from the different primary divisions of mankind.

The Polynesians. Out in the Pacific, from Hawaii to New Zealand and from Tonga

A Polynesian. The Polynesians are one of the best modern examples of a blended race. All four of the primary races have entered into their composition,





cience Servie

An inhabitant of Tibet, very similar in form and feature to some of our Indians. In southwestern Tibet about 10 per cent of the inhabitants are of this type. It is believed that they are descended from Hyperborean ancestors that came into Tibet from Europe or northern Asia and mingled with the Mongoloids of the region. Tribes of similar mixed Hyperborean and Mongoloid descent came across Bering Strait from northern Asia and were the ancestors of our Indians.

to Easter Island, lives a group of islanders noted for their skill in navigation and their agreeable manners and way of living. These are the Polynesians, a people varying individually as well as from island to island, but who are for the most part moderate in stature, light brown in skin color, with hair which varies from curly to straight and with facial features which show a blending of white, Oceanic Negroid, and Mongolian (Malay) elements. The ancestors of these people probably came from the East Indies. The Polynesians are one of the best modern examples of a well-blended race made up of many diverse elements. All four of the primary races have entered into their composition.

The Mongoloid element in the Polynesians is chiefly Malayan.

The original white element was the small, unusually dark-skinned Mediterranean type that is now found in northern India. This small Mediterranean stock is important as an element in many secondary races of the eastern tropical world.

The American Indian. The ancestors of the American Indians were the northeastern Asiatic tribes of mixed white and Mongoloid descent. It is generally agreed that they came to the New World across Bering Strait. There were many separate migrations, and in the various Indian peoples of North and South America many differences are found. In many Indians the white element is stronger than the Mongoloid. Some of them with their tall stature and massive features are much like the

RACES OF MEN

Hyperborean hunters who lived in Europe during the last ice age.

The Eskimos, who are a distinct sub-race, are much more Mongoloid in their features than are the Indians. The Indians of the northwest coast of North America are also more like the Mongoloids than are most other Indian tribes. while the inhabitants of the Amazon-Orinoco jungle region in many respects are more like Malayans than typical Indians.



An Ethiopian (above) and a Somali. They are of mixed Mediterranean and Negroid descent, the Ethiopians having the greater proportion of white blood.

Asiatic peoples of mixed white and Mongoloid descent. In western Siberia there are many tribes (Ostiaks, Samoyeds, Yakuts) of mixed white and Mongoloid stock. Also in Turkestan and southern Siberia (the region formerly known as Tartary) many of the Turkish tribes (the Tatars) are in part of Mongol blood. Moreover, in the very northeastern corner of Asia, east of the region inhabited by the Tungusic people, there are tribes of mixed white and Mongoloid descent, who live much as our Indians and Eskimos do. In Japan there survive in some of the northern islands the remnants of an ancient and primitive Hyperborean white people called the Ainu who occupied most of the Japanese Archipelago before the coming of the Mongoloids. The Japanese proper are a mixture of Mongoloids from the continent, Ainus, and Malayans. They are in the main of the Mongoloid race, but they carry a strain of Hyperborean white.

East African peoples of mixed blood. Northern and northeastern Africa is the home of a tall, brown-skinned branch

of the Mediterranean stock. The Egyptians belong to this race, as do the Berbers and some of the other North African peoples. They are spoken of as the Hamitic peoples. At one time the main population of Ethiopia and of the East African regions to the south was Hamitic, but now the Negroes have moved into the region from the west, and there has been an extensive mixing of the white and Negro stocks. Among the Amharas, or Ethiopians proper, the white element is the more important, and the Somalis and some of the other tribes of East Africa also are mainly Hamitic. On the other hand, as has been noted, the Bantus are Negroes who have been modified by a relatively slight Hamitic admixture. The relative amount of Negro and white elements in the population varies in different territories, but all down East Africa from upper Egypt south the people are of mixed white and Negroid descent.

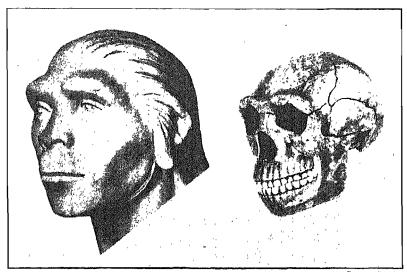
The blue jay of our Eastern states, the California jay, and the Florida jay, all differ from each other. The meadow larks of the Middle West are bigger and have a different song from the meadow larks of the Atlantic states. The red foxes from Nova Scotia westward are larger than those of regions farther south, and the central northern foxes are brighter red than the eastern ones. Animals, as they spread to different regions, become different, and although we do not know the ancestry of human races with certainty we do know that man has become different in different parts of the earth. Whether or not our theories of race origins and relationships prove to be correct or incorrect, the differences in the peoples that the theories try to explain will remain.

PROBLEM FOUR

How and When Did the Primary Races of Mankind Originate?

Geologically speaking, man is a very recent animal on the earth. Nevertheless, the differences between some of the races are marked. The weight of a Pygmy is less than half that of a Patagonian Indian and the facial features of an Arab and of a Mongol are very different. How and when did these racial differences arise? For a study of this problem some knowledge of the early history of mankind is required.

Early man. From their skeletal remains it is known that in earlier times several types of very primitive human beings existed on the earth. In museums you can see restorations of these ancient men. Two of them, the old ape man of Java (Pithecanthropus) and the Peking man (Sinanthropus), are so different from modern men that they are not even placed in the same genus with him. Some of the later races of prehistoric men are placed



Science Service

Peking woman who lived perhaps 500,000 years ago. Note the brow ridges on the skull.

in the same genus (Homo) as present-day peoples, but are regarded as separate species.

These early types of *Homo* include three species with large faces and heavy eyebrow ridges. They are Rhodesian man (*Homo rhodesiensis*) of Africa; Solo man (*Homo soloensis*) of Java; and Neanderthal man (*Homo neanderthalensis*) of Europe, Morocco, and Siberia. Neanderthal man is believed to have occupied Europe for probably fifty thousand years or more, and to have been in Europe as late as twenty-five thousand years ago, in Morocco perhaps much later.

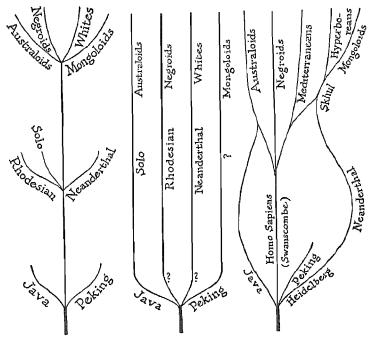
A fourth race (Swanscombe man and Galley Hill man) had features more like those of men of today. It is called *Homo sapiens*, as are all modern men. Remains of this species or race have been found in Europe and Africa, under conditions of great antiquity. Galley Hill man is supposed to be the most important human ancestor, and perhaps the only ancestor, of the human races on earth today. All these old types had brains as large as those of living men, and we have no reason to believe that any one of them was superior in intelligence to the others.

Origin of modern man. The diagrams on the next page show three theories of the origin of modern human races. All anthropologists are agreed that two hundred or three hundred thousand years ago a number of kinds of primitive men who used fire and fashioned stone tools and weapons were roaming about in different parts of the earth. The question is, what is the relation of modern man to these earlier types?

Some anthropologists think that all the old-time races except one (*Homo sapiens*) became extinct and that all living men are descended from this single surviving line. According to this theory all the different types of men we find today have been produced by the variation and spreading of this one stock in comparatively recent time.

A second theory of the origin of modern man is that a number of the old-time races lived on — that their descendants are the primary races today. The Peking man is said to have had marked Mongoloid characters and the Rhodesian man characters

that were distinctly Negroid; one prominent anthropologist considers that in these peoples the Mongoloid and Black races were marked out a half million years ago. According to this theory the division of the human stock into the primary races of today took place at an early period in the development of mankind. Each race has developed independently up to its present form from its own old-time stock.



Diagrams representing three theories of the origin of the races of modern man. The three theories agree in assuming that all human races, living and extinct, have arisen from one common ancestral stock.

A third theory holds with the first one that modern man—man derived from the *Homo sapiens* line—appeared in recent times and spread over the earth, but it holds also that some of the other races did not become entirely extinct.¹ This theory grew

¹ For a full account of the theory of the double descent of some races and a classification of European races in accordance with it see Coon's Races of Europe (The Macmillan Company). In Boas's General Anthropology (D. C. Heath & Co.) the theory is clearly stated by MacGregor and disagreement with it is expressed.

out of studies made in connection with the peoples of Europe and we shall consider it briefly as it applies to the white race.

Origin of Caucasian race. Somewhere in eastern Africa or southwestern Asia there arose a food-producing people who kept domestic animals and cultivated the land. These people are spoken of as the Mediterraneans. They had narrow long heads like the Swanscombe man and the Galley Hill man and were rather slender and finely built. The civilized peoples of the ancient Caucasian world — Sumerians, Egyptians, Chaldeans, Hittites, Phoenicians — were Mediterraneans. They are accounted as descendants of the early human line that has been given the name *Homo sapiens*.

At the same time that the Mediterraneans were developing their civilization and agriculture, there was in Europe and across northern Asia and in northern Africa a race of hunting men — food collectors and not food producers. The hunters were larger than the Mediterraneans and the men were much larger than the women. In the skeletons of these people that have been found, the skulls have bony ridges (brow ridges) above the eyes and the skull and limb bones are much roughened where the strong muscles were attached. They were a heavily built, rugged race who lived by hunting the mammoth, the woolly rhinoceros, and the cave bear. They are sometimes called the Hyperborean, or Northern, race. The Cro-Magnons who made the famous drawings in the caves of France and Spain were of the hunting race.

According to the theory we are presenting, this hunting race was descended chiefly from the same stock as the Mediterraneans (the old *Homo sapiens* stock) but in part from the Neanderthal race that occupied Europe at an early date. The theory also holds that some of the peoples living in central and northern Europe today are descended from the Hyperboreans and therefore that some modern European races trace their ancestry back to both the original *Homo sapiens* stock and to another (Neanderthaloid) old-time race.

The idea is that the present-day Mediterranean branches of the white race are of pure descent from one old *Homo* race; the

Hyperborean races, while mainly of this same stock, carry an infusion of blood from a bigger and more powerful line.

Origins of Australoids, Negroids, and Mongoloids. The diagrams (page 73) indicate the origins of the three non-Caucasian races according to the theories outlined above. According to the third theory the Australoids are descended from a cross between *Homo sapiens* and Solo man; the Negroids are of pure sapiens descent, while the Mongoloid race is looked on as a branch of the Hyperborean. Some believe, however, that the Mongoloids are hybrids between the Hyperboreans and a descendant of the old *Sinanthropus* line. A line in the center diagram from the white to the Mongoloid branch would indicate this relationship. Little is really known of the origin of the Mongoloid peoples, but they seem more nearly related to the Hyperborean whites than to any other race.

Considering the fact that man is so recent an animal, it is rather peculiar that he knows so little of his own origin. Our knowledge of early races is in most cases derived from only a few specimens and the theories as to the origins of modern races are all likely to be revised. In the next problem we shall consider the subdivisions of the Caucasian peoples, based on the idea that they are in part of Mediterranean and in part of Hyperborean descent. No two authorities give the same classification of races. This one is an attempt to arrange the white peoples in groups according to their biological relationships rather than by nationalities or the languages they speak.

PROBLEM FIVE

What Are the Principal Branches of the Caucasian Race?

Ten thousand years ago, Europe, northern Asia, and northern Africa were occupied by Hyperborean hunters. The Mediterraneans had appeared in western Asia and northeastern Africa. Whatever their ancestry may have been, these two groups of peoples were present in the regions indicated and their descendants make up the main body of the white race. A tabulation of the more important subdivisions of the race is given on the next page.¹

THE MEDITERRANEANS

The Mediterranean peoples are characterized by a narrow long head which is especially well developed in the lower back part. The nose is narrow. In most branches of the race the tendency is to dark hair and eyes and to swarthiness of skin. Among some of the European Mediterraneans, however, blue eyes and blondness are common. The build is inclined to slenderness. The bones as compared with some other races are not heavy and there is an absence of cragginess in the features.

Distribution and spread of Mediterraneans. The Mediterranean race is at present spread over a wide area from western and central Europe to Burma on the east. It includes the chief element in the populations of Spain and southern Italy, the peoples of northern Africa, eastern Africa (the Hamitic peoples), and the Arabs, Afghans, and northern Hindus. The Mediterraneans also form a large element in the population of many other regions, either in pure or in mixed form.

The Mediterranean line is regarded as the chief stock of the white race and perhaps of the whole human race. It originated probably in western Asia. From the place of its origin it spread through northern Africa and down the East African coast. To

¹ The classification here given is based essentially on the ideas presented in Coon's Races of Europe (The Macmillan Company), and the photographs used in this problem are all taken from the pictorial atlas which is a part of that book.

BRANCHES OF THE CAUCASIAN RACE

1. Races of Mediterranean descent

a. Small Mediterranean

c. Irano-Afghan d. Nordic

b. Atlanto-Mediterranean

2. Races of Hyperborean descent

.....

a. Brünn

b. Borreby

c. Alpine d. Ladogan

3. Races of mixed Mediterranean and Hyperborean descent

a. Dinaric. Mediterranean-Alpine intermixture

b. Noric. Nordic-Alpine intermixture

c. Armenoid. Alpine-Irano-Afghan intermicture

d. Neo-Danubian. Mediterranean-Ladogan intermixture

e. East Baltic. Borreby-Nordic-Ladogan intermixture

the east the Mediterraneans extended their range across Afghanistan and India, and north around the Caspian Sea to the steppes of Asia. About 3000 B.C., well after the glaciers had retreated, they invaded Europe from the south and east and settled in the countries along the Mediterranean Sea. Later others worked around the Atlantic coast of Europe by sea to the British Isles and Denmark. In the meanwhile, members of a third branch made their way up the Danube basin to central Europe. At a comparatively recent date tribes of them from north of the Caspian Sea crossed Europe by a more northerly route and reached Scandinavia and other countries of western Europe. As the Mediterraneans advanced in Europe they met the people of the Northern race already in possession of the continent and in many places blended with them. In consequence most Europeans of today are of part Mediterranean and part Hyperborean descent.

Types of Mediterraneans. The four generally recognized types of Mediterraneans are the small Mediterraneans, the Atlanto-Mediterraneans, the Irano-Afghans, and the Nordics. Since the Nordics are often classed as a separate race, coördinate with the Mediterranean, we shall discuss them separately.

The small Mediterraneans are fine-boned and slender people. Most of the Spaniards and southern Italians are of this type; also the Arabs, ancient Egyptians, and some of the Danubian people.



A New England small Mediterranean of colonial descent. The bones are fine. The hair and eyes are brown.

Much of the population of the Midland factory area of England and of the Scotch industrial region along the Clyde is of the small Mediterranean stock, and the people of the south of France are largely of this type. The skeletons of the ancient Egyptians show that they were a slender Mediterranean people very similar to the small Mediterraneans of today. Most of the Northern Hindus belong to a special dark-skinned branch of the small Mediterranean stock.

The Atlanto-Mediterraneans are a more robust strain. They make up much of the population of northern Africa (Moors, Berbers, Tuaregs, Kabyles); they are found in Crete, Greece, and the eastern Balkans; and they occur in Portugal, eastern Ireland, Wales, and along the western coast of Scotland. The Atlanto-Mediterraneans are larger and taller than the small Mediterranean type. The Hamitic peoples of northern and eastern Africa are a special branch of the Mediterraneans closely allied to the Atlanto-Mediterraneans.

The Irano-Afghans are found in Persia and Afghanistan and extend eastward across into India. They are taller than the small Mediterraneans, and often have long faces and hooked noses. They are heavier and have heavier beards. The Turks are mainly of this race. The Turks of Asia Minor, however, are in



An Italian Atlanto-Mediterranean, a good example of the race.



At left is a Spanish Atlanto-Mediterranean. His height is 6 feet 1 inch. Center and right is a Riffian boy of Morocco. The straight vertical sides of the head and face in the front view show a tendency toward Nordic characteristics.



An Atlanto-Mediterranean from Ireland. The eyes are blue and the hair black. The breadth of the forehead indicates an admixture of Hyperborean blood.

part Alpine, while those who live east of the Caspian and south of the Aral Sea are intermixed with Mongoloid blood.

The Nordics. The Nordics are by some classed as a separate race and by others as a northern branch of the Mediterra-



An English Nordic of a type that was formerly found in central Europe and is now most common in Sweden and eastern Norway.

neans. A people regarded as the forerunners of the present-day Nordics are called the Protonordics and are supposed to have originated from a Mediterranean stock that worked its way around the Caspian Sea and settled to the north of it. They were keepers of horses and have been called the "Horsemen of the Steppes." They

made impressions on their pottery with cords and in anthropologies are called the "Corded People."

The Proto-nordics moved westward about four thousand years ago, bringing horses into Europe for the first time. In central Europe they met a race of small Mediterraneans (called Danubians) who had made their way up the Danube Valley and the blend of the two peoples produced the Nordics. The Nordics left much of their blood in central Europe and they continued westward until they reached Scandinavia, Holland, and the British Isles. The dominant element at the present time in the population of England, Scotland, Norway, Sweden, and Holland is Nordic. In its purest form the race is found in the valleys of eastern Norway and in Sweden. By migration the Nordics were transplanted to North America and the great center of Nordic population now is in Canada and the United States. The Nordics are often blond, but blondness and blue eyes are found in other races also; hence light hair and eyes do not necessarily imply Nordic blood.



An American Nordic of Colonial descent. He is of the rather large Protonordic type that first came into Europe from the steppes of Asia. The eyes are blue, the hair ash blond.



A young man of pure Nordic type from Finland.



A Nordic boy of Portugal.

The unmixed Nordics, like the other Mediterraneans, are long-headed and inclined to fineness of bone and slenderness of build. Owing to their geographical location, however, the Nordics have for a long time been in contact with the large Hyperboreans of Europe (Brünn, Borreby) and have absorbed some of these elements. What is usually considered a Nordic is in reality the original Mediterranean Nordic plus an added Hyperborean strain. The introduction of this Hyperborean blood has increased the weight and stature of the Nordics as a race above that of the other Mediterraneans. It has also added to the width of the head and face.

DESCENDANTS OF THE HYPERBOREANS

Four distinct races of Europe — Brünn, Borreby, Alpine, and Ladogan (la'do-gan) — are classified as being of Hyperborean descent. As has been stated, these peoples represent a bigger, more powerful race than the Mediterranean. All the four subraces are distinct, but only the Alpines are numerous. The accompanying photographs show extreme rather than average types of these races.

The Brünn race. The Brünn race gets its name from the fact that certain old skeletons supposed to be characteristic of the race were discovered in a cave at Brünn, Moravia. At present the race is found in western Ireland, at the southern tip of Sweden, in southeastern Norway and in the mountains of Norway, and at scattered places in the north of Scotland and the east of England. The men of this race are very large, many of them weighing 200 pounds. The heads are long and the skull capacity great — the heads of the people of western Ireland are the largest known in the world. In a typical member of the Brünn race the eyes are wide apart. The hair is brown and the eyes are usually gray or blue.

The Borreby race. The Borreby men are large, though perhaps not quite so tall as the Brünns. The head is wider than in the Brünns in proportion to its length. It is high in front and

¹ Possibly the Hyperboreans of western Ireland should be considered as an independent type rather than as Brünns or Borrebys.



A Brünn man of Swedish descent. The height is 6 feet ½ inch, and the weight 204 pounds. The hair is brown and the eyes are blue.



A Borreby man from Denmark. The head is both long and wide and the cranial capacity very great. The height is 6 feet 2 inches, and the weight 210 pounds.



An Alpine from France. The head is high and is short from front to back.

tends to be straight across the top and down the back. The face is wide. There is more of a tendency to light yellow hair and blondness than in the Brünns.

The Round Barrow men who invaded England and buried their dead in round mounds were partly of this Borreby race, as the skeletons in the mounds show. At present the type is found most commonly in northern Germany, where it forms the most characteristic element in the total population. It is found also in northern Denmark, in southern Norway and Sweden, in western Ireland, and in Holland and Belgium. Traces of it also occur in England, Scotland, and other places. The people of Iceland are mainly of the Borreby type.

The Alpines. The Alpine race and its intermixtures with other races make up a great part of the population of Europe. This race is found along the highlands all the way across Europe from west to east, and also in the mountains of western central Asia. Probably the greatest Alpine center lies in France and southern Germany, while a considerable part of the population of Belgium, northern Italy, what used to be Austria, and the Balkans is Alpine. The Alpine people are smaller than the Brünn and Borreby men. They are stockily built, in contrast to the leaner, flatter build of the Mediterranean peoples. Both their heads



A Ladogan of Hungary. Ladogans of pure type are rare, but most of the people of eastern Europe are in part of Ladogan descent. It is Ladogan rather than Mongoloid blood that gives the "Asiatic" cast of features to individuals among the peoples of central and north central Europe.

and faces tend to roundness, with little projection of the head at the back; the nose tends to roundness also, and the hair of the head and beard is abundant and wavy. As a rule the hair is brown, while the eyes vary from brown to blue.

The Ladogan race. The Ladogan race is named for Lake Ladoga in northeastern Russia, not far from Leningrad. At an earlier time the Ladogans occupied a large forest area in northern Europe, but now as a pure race they are not numerous. However, they form a main element in the population of much of the lowland country of eastern Europe. In size they are, like the Alpines, smaller than the Brünn and the Borreby peoples. The head is broad, the eyes are wide apart, the cheeks prominent, the nose is flattish and low bridged, with a snubbed tip, and there is strong tendency to blondness. The Lapps are primitive relatives of the Ladogans, who moved into Europe from the east.

WHITE RACES OF MIXED DESCENT

There has been, of course, a mixing of Hyperborean and Mediterranean blood over a long period of time, and a number of recognized sub-races have grown out of the combination of the two white stocks. A few of the more important of these white peoples of mixed descent will be mentioned.

Alpine-Mediterranean mixtures. Many of the Swiss, northern Italians, Austrians, and Balkan peoples belong to the Dinaric race, which was formed by a mixture of Alpines with



An Armenoid, showing the Irano-Afghan face and nose and the Alpine cranial form.



A Noric from Czechoslovakia. The Norics are of mixed Nordic and Alpine descent.



A Russian Neo-Danubian. The Neo-Danubians are a mixture of Ladogan and Danubian (small Mediterranean) stocks.



An East Baltic. The East Baltics are a mixture of Borreby, Nordic, and Ladogan. The example shown tends to the Borreby type and has a larger head and rounder face than is typical of the race.

Atlanto-Mediterraneans and small Mediterraneans. In this race there is a tendency for a broad, short head to be accompanied by a long, narrow face and a prominent nose. Thus the Mediterranean facial features and the Alpine head shape have been separately combined in inheritance, rather than blended.

Two other races of general Dinaric type are the Noric and Armenoid. The Noric has been formed by a mixture of Nordic and Alpine. It is a blond type very common in eastern Germany. The Armenoids are a mixture of Alpine and Irano-Afghan Mediterranean. They are dark-skinned and have extremely long faces and long noses. Many of the Armenians belong to this race.

The Neo-Danubians. The rather short, snub-nosed, pink-cheeked farming population of eastern Europe is for the most part Neo-Danubian, a race formed by the intermixture of the small Mediterraneans (Danubians), who made their way up the Danube basin into Europe about 3000 B.C., with the older Ladogan forest people. The Neo-Danubians are found either as a major or a minor element in the population over a wide area.

The East Baltics. East Baltic peoples (Finns, Esthonians, Latvians, Lithuanians, East Prussians) are a mixed group which includes Brünn, Borreby, and especially Ladogan elements in combination with Nordic, and especially with the larger Proto-Nordic branch of that race. Some of the East Baltics are among the largest and blondest peoples in Europe. Typical of this combination is a squarish head, wide face, and snub nose.

The human stock has developed into many races, each with certain distinguishing characteristics. Why do these differences arise? Under what conditions does a plant or animal species tend to become uniform and what conditions favor diversification? Possibly you will be interested in these statements made by Dr. Paul Bartsch of the United States National Museum: "Hybridization gives variation. Isolation gives fixation. Fixation gives speciation." By fixation is meant the developing or fixing of a uniform type, so that all members of the group are closely alike. By speciation is meant the development of a species.

PROBLEM SIX

How Can We Account for the Great Number of Different Kinds of Plants and Animals on the Earth?

Biologists think that the earth is very old; that hundreds of millions of years ago a simple form of life appeared on it; and that all the different living things on the earth today have developed from this first simple form. We cannot at this point stop to consider the evidence in support of this theory; for the present let us accept it merely as a hypothesis. The theory assumes that the forms of living things are not fixed but that from generation to generation they can change. Our subject in this problem is how these changes are brought about — how different species of plants and animals originate.

Development of differences. As we saw in our study of the law of normal variation, *living things vary*. Offspring are not exactly like their parents. They differ also from each other. We know this. Plant a row of radish seedlings in the garden and watch them. Some grow quickly and make fleshy roots. Some come on more slowly. Some never will make radishes fit for eating but send their growth into leaves and a flowering stalk. It is a simple fact of nature that there is variation in living things.

A second fact of nature is that living things must struggle for existence. Plants produce so many seeds that there is not room for all the young to grow. Animals multiply so rapidly that there is not food for all. So many living things are produced that over the whole world there is a struggle among them for place and food. In this struggle only those best fitted to the conditions in which they live are able to survive. The less well adapted are crowded out. There is a natural selection of the fittest to survive.

The theory is that the offspring of living things may differ from their parents and from each other, that they struggle for existence, and that those best adapted to meet the problems of life are the ones that survive. This process would in time lead to the production of many different kinds of living things, for no one kind of plant or animal could be best fitted to all kinds of different living conditions and to all different ways of living. As time passed and the differences in forms became greater and greater the earth would finally have plants and animals of many different kinds.

Radiative adaptation. The theory of the origin of new kinds of plants and animals has been called the theory of *radiative* adaptation. Let us see how it might be supposed to work.

Suppose that there is a wide land like our own but entirely without animals. It is a land of mountains and forests and deserts and grassy plains, cold in some parts and warm in others. It has streams and swamps, lakes and ocean shores. Let us suppose that in the midst of this land a pair of small animals are turned loose — animals of a kind that would be able if need be to dig a hole, swim a stream, climb among the branches of a fallen tree, live on either animal or vegetable food. If nothing should interfere, what types of animal life would be found in this land at the end of 100 million years?

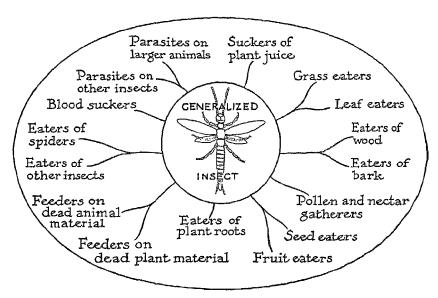


Diagram suggesting some of the ways insects might vary in becoming adapted to different food supplies.

We may be sure that in what would be geologically a very short time the animals would multiply until our whole supposed land would be occupied by them and that differences in the animals Some kinds would gradually develop that would be would arise. good climbers and that would take to the forests. Some would excel as swimmers. Some would be fleet of foot and would choose as their home the grassy plains where they could outdistance all pursuers. Some would be of a fierce nature and have weapons that would enable them to live by devouring their fellow animals. As time passed there would be more and more variations and through slow changes we should have animals of quite different The ones best suited to the conditions in the regions where they lived or to their ways of living would always be the ones that survived. At the end of 100 million years we should find kinds of animals that differed very markedly from each other.

Survival of the unlike. A plant or an animal that is different from others may have an advantage because of its un-It may be able to live in a region others do not occupy or in a way different from that of its neighbors, thus escaping The squirrels of our forests and the monkeys of the competition. tropics by their ability to climb have found a home for themselves The muskrats to a considerable degree have the in the trees. The snowshoe rabbit, because of its marshes to themselves. ability to resist cold, run on snow, and feed on twigs, can live in the In the spring in our northern woods we find a whole far north. group of early-flowering herbs (trillium, hepatica, bloodroot, Dutchman's breeches, spring beauty). They are able to live on the forest floor because they do most of their growing before the leaves appear on the trees and cut off the sunshine from the earth below.

Look about you anywhere and you will find examples of small plants and of comparatively helpless animals (e.g., earthworm, hummingbird) that are able to live because they are adapted to some special location or way of life. A principle of nature is the survival of the unlike.



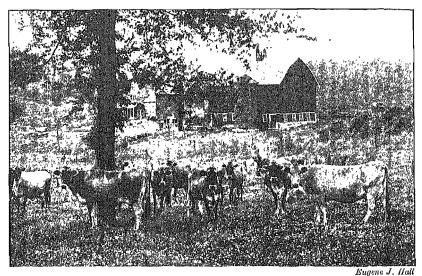
J. Horace McFarland

The bloodroot furnishes an example of the survival of the unlike. Because of its habit of early spring growth, it is able to produce its flowers and seeds before the leaves on the trees cut off the sunlight from the forest floor.

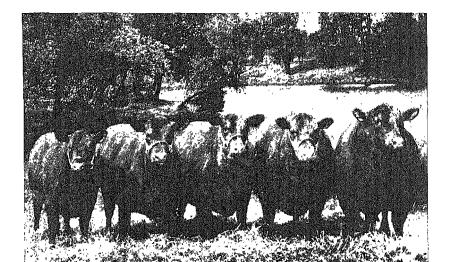
Origin of varieties of domestic plants and animals.

The plants and animals we know the most about are the ones we cultivate and domesticate. In these plants and animals we have an opportunity to see differences in individuals. We control their breeding and in them we can compare parent and offspring. Do domestic animals and cultivated plants show the tendency to vary and change that we have supposed to be present in plants and animals in the wild? Is it possible to establish different varieties and breeds of these plants and animals by selecting and perpetuating variations that appear among them?

At any animal show you will see many different breeds or strains of the same species. These have been established by selecting individuals that showed variations and by breeding from these individuals. Any seedsman's catalogue will give you long lists of varieties of flowers and vegetables developed by breeding from selected plants that showed differences. Such varieties survive because they are selected by man as those that best serve



Jerseys in clover.



Prize Aberdeen-Angus steers.

Arthur M. Prentiss

The two breeds of cattle shown above are both descended from the wild cattle of Europe. One breed has been selected and bred for dairy production. The other has been developed as a beef breed. The difference in them now is easily visible. It is not mere unproved theory that plants and animals in the course of generations can change.

his purpose. So among wild animals and uncultivated plants nature selects for survival those varieties that are best adapted to any given environment or for living in a particular way. Among the variations that appear there is a natural selection of the fittest to survive.

Distribution of plants and animals. The way plants and animals are distributed over the earth is interpreted as evidence for the correctness of the theory of radiative adaptation. Generally speaking, the plants and animals of widely separated areas are not so closely related as are those that live in the same regions. Australia is the most isolated of all the continents and its animals are marsupials (mar-sū'pĭ-als) and are very different from the animals of other continents (page 426). South America and South Africa are also somewhat isolated and each has a number of animal families found nowhere else. When the Americas were discovered many plants and plant genera were found in them that did not grow in the Old World and many of the Old World plants did not grow in the Americas.

This tendency to a closer relationship of the different kinds of plants and animals in the same region is looked on as an argument for their origin by radiative adaptation in each area. Some kinds originated in one area and some in another and in consequence the fauna (animals) and flora (plants) of different regions differ. Usually a species has a *continuous distribution* over the area where it is found. It does not occur in scattered spots here and there but covers the whole area as though it had originated in one place and had spread out from this as a center. The interpretation of discontinuous distribution has been given under the discussion of the Pygmies on page 62.

Variation in behavior. The ladybug or ladybird beetles are a family of small carnivorous beetles. They move about on plants, scooping up plant lice, scraping off and devouring scale insects, or feasting on the eggs and young of other insects that they find on the plants. They are fierce, active little creatures well adapted to their way of life and accounted great friends of man because they destroy garden and orchard insect pests.

The figure below shows two species of ladybugs that have changed their diet and manner of living. Instead of eating other insects, one species feeds on the leaves of melons and squashes. The other is the Mexican bean beetle, which is a great garden pest because it devours the leaves and young pods of the bean. These two beetles in form and structure do not differ essentially from their carnivorous relatives. They have no special adaptations for living on a vegetable diet. The change that came in them was something that caused them to eat leaves instead of insects. They









Ladybug

Melon beetle

Mexican bean beetle

A ladybug and two vegetarian relatives. The ladybugs are little beetles that live on plant lice and other insects. A few of them, without any particular change of structure, have taken to a vegetable diet. It is believed that the first change in the formation of many new species is the instinct to live on a new kind of food or to live in a different way.

differ from the other ladybugs in an invisible way that caused them to turn to a new diet and to take up a new way of life.

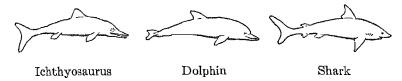
It is believed that the first step in the formation of many new animal species is a variation in behavior that causes the animal to live in a new way. Then other variations arise that adapt it to this mode of life. According to this idea, the carnivorous animals may not have become killers because they had fangs and claws, but because they preferred meat. After they took to a predatory life, the ones that developed the best teeth and claws survived, and thus they gradually became adapted in their structures for the life they lead. In time the bean beetle will probably become different in its mouth and digestive parts from its relatives that live on meat. Note that the variation that caused it to change to a vegetable diet opened to it a great additional food supply.



Examples of parallel development. The illustration shows a flying frog, flying lizard, flying squirrel (above), flying lemur, and at the bottom a flying phalanger (page 429). All these are tree-living animals and each has developed independently organs that enable it to glide from bough to bough or to pass from tree to tree without coming to the ground.

Parallel development. In becoming adapted to meet their life problems, organisms that are not related often develop parts that have the same function. For example, a cactus and a porcupine are both covered with spines. Each has developed for itself this means of protection from animals that might feed on it. A bird and a bat both have wings. They are not related, but each for itself has developed organs that give it the power of flight. This independent development by unrelated organisms of parts that have the same function is called parallel development. The illustration above shows one example of it. In the plant and animal kingdoms you can find hundreds of other examples. Various kinds of living things meet the same life problems and in solving these problems they often hit on the same plan.

A point to be noted is that by parallel development plants and animals that are not closely related may come in a general way



Example of convergent development. In becoming adapted for water life the ichthyosaurus (an ancient reptile), the dolphin (a mammal), and the shark have become similar in form.

to resemble each other, as is shown in the illustration above, of three kinds of water-living vertebrates. This becoming alike of unrelated organisms through adaptation to the same environment and way of living is often spoken of as convergent development. Instead of diverging or becoming more unlike by the changes that take place in them, the organisms tend to become more alike. In classifying plants and animals we must distinguish between similarities owing to blood kinship and similarities that arise in unrelated forms through convergent development.

The key idea in the theory of radiative adaptation is that living things vary and give rise to offspring different from themselves. This idea is accepted without question by the public mind. Farmers and gardeners take it for granted that new varieties and breeds of plants and animals can be established. Most persons believe that all living human beings, whatever the differences between them may be now, are descended from the same stock. In the belief that new types of living things can arise through variations in previously existing kinds, scientific biology and the public mind are in accord.

FACT AND THEORY IN SCIENCE

In science we follow nature. We start with the facts, and in all our reasoning and explanations these are our guide and final authority. The facts exist in nature and are independent of us. Our theories are only explanations of the facts, and whether they be right or wrong the facts remain unchanged.

As we begin our study of biology we are faced by the fact that there is in the world a tremendous number of different kinds of living things. We see at once also that the differences among these living things adapt them to various living conditions and various modes of life. The whiteness of the arctic animals makes them hard to see against the snow; the spots of the ocelot and the leopard blend with the patches of sunlight and shadow in their forest home. The plants that grow in forest shade have broad, thin leaves; most desert plants have no leaves. A bird has wings and a fish has fins. It is a simple statement of fact to say that living things are diverse and that their diversities fit them to meet the conditions of their lives.

The theory of radiative adaptation is offered as an explanation of these facts. According to the theory, plants and animals in the course of their generations are changed and molded to meet the requirements of their existence, and the individuals and types best adapted to their life situations are the ones that survive. The theory seems reasonable. You will see for yourself that if life should develop in accordance with it over a long period of time, the result would be the production of living things of many kinds. Adaptation *must* lead to diversity, for there are many different conditions and many ways of living in the world.

Science requires of a theory that it shall explain all the pertinent known facts and shall not be contradictory to any of them. As your course in biology proceeds you will be better able to judge whether the theory of radiative adaptation meets this test. As our study of human races shows, the mixing of varieties is a part of the general biological situation that must be taken into account when the origin of species is considered.

UNIT COMPREHENSION TEST

- A. Why is it necessary to have a systematic method of naming and classifying plants and animals? What are the divisions of the classification scheme? What two names together make the scientific name? How are capitals and italics used in writing scientific names? What is the purpose of the species description? Upon what basis are plants and animals usually classified? What difficulty is often met in classifying plants and animals? Give a brief account of the man who originated the double-naming system. How long ago was he born?
- B. What is the scientific name of the human species? What are some of the characteristics that are considered in the classification of human beings? What are the four primary human races and the distinguishing characteristics of each? What are the subdivisions of the Caucasian race? What are the two divisions of the Australoid race and where is each found? Discuss briefly the divisions of the Negroid race. What is discontinuous distribution and how is it interpreted? What are the subdivisions of the Mongoloid race? Name and discuss a number of secondary races that have been formed by mingling of the primary races.
- C. What reason is there to believe that man has been on the earth for several hundred thousand years? What are the three theories of the origin of the primary human races of today? Explain the double-descent theory of the Hyperborean race.
- D. Tell briefly of the distribution and spread of the Mediterraneans. Discuss briefly the subdivisions of the Mediterranean race. What are the subdivisions of the Hyperboreans and the characteristics and geographical location of each subrace. What primary racial elements have entered into each of the following: Dinaric; Noric; Armenoid; Neo-Danubian; East Baltic? What are the physical characteristics and the geographical location of each of the above? How is race distinguished from nationality?
- E. Upon what three facts of nature is the theory of radiative adaptation based? Why does radiative adaptation supposedly result in the development of different kinds of plants and animals? What is the advantage in unlikeness? Compare the origin of breeds of domestic animals and of varieties of cultivated plants with the origin of different varieties of living things in nature. What evidence is found in the geographical distribution of plants and animals for the theory of radiative adaptation? How may variation in behavior result in the formation of a new species? How is this illustrated by the bean beetle? What is meant by parallel development? What examples of parallel development do you know?

SUGGESTED ACTIVITIES AND APPLICATIONS

- 1. Define all terms used in the text of the unit that are set in boldface italic type.
- 2. Under the Order Primates man belongs to the Suborder Anthropoidea (monkeys, apes, man) and to the Family Hominidae. Write out in full the classification of the human species.
 - 3. Class project:

Let the members of the class clip pictures of plants and animals from any available source and arrange them by phyla and classes. Paste the pictures on large cardboard sheets and place these on the schoolroom walls. The purpose is to get a general idea of the chief plant and animal groups.

4. Clip pictures of men and arrange them by races according to the outline on page 61. Paste the pictures in your notebook, or the exercise may be made a class project and the pictures pasted on large cardboard sheets and placed

on the walls of the schoolroom.

5. The photograph at the right is that of a noted writer, author of the book, *I See a Wondrous Land* (G. P. Putnam's Sons, New York). To what race would you say he belongs?

6. Obtain a copy of Coon's Races of Europe (The Macmillan Company, New York). Then clip from newspapers, magazines, and other sources a large number of photographs of men and women of the white race and arrange them as nearly as you can according to the outline in Problem Five. Include in your collection photographs of those prominent in sports, aviation, business, educational, and political life, and on the



stage and screen. Try to get profiles as well as front views. Give particular attention not only to the shape of the head but also to the width and general outline of the face and to the shape of the nose. The photographic atlas in the volume referred to above will aid you in the arrangement of your material.

The photographs may be pasted in your notebook, or the undertaking may be made a class or group project and the photographs pasted on large cardboard sheets for placing on the schoolroom walls. To help in fixing the various racial types in mind, it will be best at first to include in the collection only photographs that conform somewhat closely to the accepted race characteristics.



A separate collection of the doubtful photographs may be made and studied for their probable relationships.

- 7. Give examples of parallel development that are not mentioned in the text.
- 8. The small shrimps (Caprella) shown at the left live among seaweeds where currents run strong. Do you note any special adaptations to their habitat (place of living)?

General References

HEGNER, ROBERT W. and JANE. Parade of the Animal Kingdom. The Macmillan Company, New York; 1935. Gives a general view of the animal kingdom, with many excellent photographs.

Nature Magazine, 1214 Sixteenth Street, N.W., Washington, D. C. A monthly magazine devoted chiefly to the biology of the outdoors. It is notably well illustrated with photographs and drawings, and each issue carries articles of biological interest. A school section is provided which suggests biological activities appropriate to the season.

Palmer, Ephraim L. Fieldbook of Nature Study. Slingerland-Comstock Company, Ithaca, New York; 1929. Highly useful for the great amount of definite information it gives about plants and animals likely to be studied in an elementary biology course and for the illustrations and other helps furnished for identification of species. Covers both plant and animal biology.

Transeau, Edgar N. General Botany. World Book Company, Yonkers-on-IIudson, New York; 1923. Valuable for botanical reference.

Wells, H. G.; Huxley, J. S.; and Wells, G. P. Science of Life. Doubleday, Doran & Co., Inc., New York; 1931. Contains a wealth of biological information. The most comprehensive single reference book.

The workbook made to accompany this textbook provides full directions for carrying out the activities suggested at the ends of the various units and is arranged for convenient recording of results. It is taken for granted the students will have access to this workbook for reference at least.



Nature Magazine

UNIT 3 THE UNITY OF LIFE

Underlying all the diversities of life there is a fundamental unity.

[&]quot;Each of her works has an essence of its own; each of her phenomena a special characterization; and yet their diversity is unity."

RESEMBLANCES AMONG LIVING THINGS

QUESTION FOR CLASS DISCUSSION

What is different in the way a crystal grows and the way a living thing grows?

LIFE presses itself into the mold of its environment, yielding endless diversification and limitless variety. It develops and changes, taking new forms. Yet notwithstanding all the differences that we find among them, all living things are in certain ways alike. Underlying the manifold diversities that exist in them there is a fundamental unity. All the various kinds of living things are but different models of the same life machine.

The living substance of all plants and all animals under a microscope appears the same. In all of them it is similar in chemical composition and is organized into microscopic units that are basically the same. All living things are alike in the way they use food and in their manner of obtaining energy. They are all alike in having the power of growth and in being able to reproduce themselves and thus provide for the continuance of their kinds. In the very fact that life resides in them and in them alone, living beings have a common quality that sets them apart from things that are not alive.

The resemblances among living things are explained by the theory that they are all akin and that the different groups of them are related as are the branches of a tree. As was stated in Unit 2, biologists believe that the different forms of life that are on the earth today have developed from one first simple kind. They are all supposed to trace back to the same ancestry, and if this belief is correct, it is not surprising that they are alike in their basic structure and their fundamental life processes; that man in his physical being has much in common with the grass of the field and the strange creatures of the ocean's depths.

The fundamental resemblances that are found among living things are accepted as evidence for the unity of life. Some of these resemblances are so obvious that we take them for granted, and with many of them you are already familiar. Our present study will be devoted more to facts and conclusions that have come out of scientific investigations. The microscope, the methods of modern chemistry and physics, and the study of organisms in their early life stages have given us much information concerning structures and processes that show the oneness of the world of life.

Problems in Unit 3

- 1 What basic similarity in structure is found throughout the world of life?
- 2 What evidence for the unity of the living world do we find in the chemical composition of living matter?
- 3 What uniformity is there in the method by which living things obtain their energy?
- 4 What uniformity do we find in the way living things reproduce?
- 5 What evidence for the kinship of living organisms do we find in their growth and development?

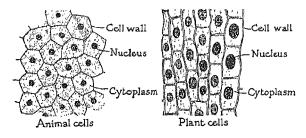
PROBLEM ONE

What Basic Similarity in Structure Is Found throughout the World of Life?

When we look at a field of ripening wheat from a distance, it appears like a great golden carpet spread upon the earth. When we come near we see that the covering of the field is not a single object but is made up of the many separate stalks of the wheat. So when we look at the body of a plant or an animal it seems to be one whole, but when we examine a portion of it under a microscope we find that it is made up of many little parts. These small parts, or units, are called *cells*. All plants and all animals are made of them. The cell is the building unit in the world of life.

A study of cells. Suppose we have under the microscope a very thin section (or slice) of tender growing root tip. We see at once the cells of which it is made. Each one has a wall about it. Within the cell is a clear material like thin jelly or raw white of egg. This is the protoplasm — the living substance of the cell. The protoplasm is divided into a denser inner part called the nucleus and a lighter outer portion called the cytoplasm. Both cytoplasm and nucleus are alive and so far as we know life does not exist except in them. Together the nucleus and the cytoplasm make up the protoplasm of the cell. It is the protoplasm of the cell that uses food and oxygen and is alive.

Now suppose we examine a very thin section of the liver of an animal. Like a root tip it is composed of cells. Each cell has a



The cell is the building unit in the world of life. Plant and animal tissues are composed of these small parts.

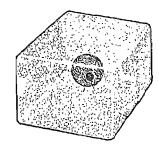
wall about it. In each the space within the wall is filled with protoplasm. In each there is a denser nucleus surrounded by the lighter cytoplasm. The plant and animal cells are essentially the same.

We see at once from their structure the kinship of plants and animals. The living part of each is made of protoplasm. In each the protoplasm is divided into the little units we call cells. A plant or an animal may consist of but a single cell. It may, if it is a large one, be a colony of billions of cells. Whether it be

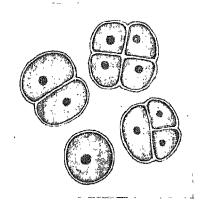
large or small, everything that is alive is built of cells.

Form of a cell. As you look at cells they appear flat as if they had no depth, no thickness. This is because the microscope focuses in only one plane. In reality the cells have height or thickness as well as length and breadth. Perhaps you can think of one of them as a tiny room and of yourself as being in the room. If you could stand within a cell you would find a floor under your feet, a ceiling over your head, and walls enclosing you all about. Think of cells as box-like or sac-like little affairs that have height. length, and breadth.

One-celled plants and animals. On walls, rocks, and the bark of trees you will find a fine growth that looks like a greenish yellow stain. This is a minute plant called *Pleurococcus* (ploor'o-kŏk'us). It is found



A cell shown in three dimensions. Under the microscope cells appear flat, but they have thickness, or depth, as well as length and breadth.

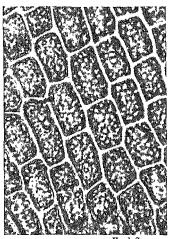


Pleurococcus, a one-celled plant. After the cells divide they separate and each one becomes a complete plant.

more abundantly on the north sides of objects, and on trees it occurs especially in the cracks of the bark, where it is somewhat protected from drying.

If you will scrape off a little of this green material and examine it in a drop of water under a microscope you will find that it consists of a multitude of tiny green cells. Sometimes the cells are seen sticking together in pairs or in little groups or colonies, but many of them lie alone. Each one is a complete plant; the one little cell performs all the functions of the root, stem, and leaves of a higher plant.

There are other one-celled plants and also many kinds of one-celled animals. With a microscope you can easily find these small beings in water brought in from ditches or pools. Some kinds move only slowly or not at all. Some swim actively about.



Hugh Spencer

Cells in the leaf of a moss plant photographed through a microscope. The lightappearing bodies within the cells are the chloroplasts. Like Pleurococcus they are lowly forms of life that consist of but a single cell.

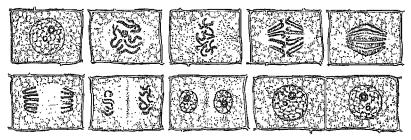
Differences between plant and animal cells. Green plants can make their own food. Animals cannot do this. The difference between the green plants and animals goes back to a difference in their cells. The green plant cell has dense spots in the cytoplasm that under the influence of light manufacture a green pigment called *chlorophyll*. The chlorophyll gives a green color to the little bodies in which it is formed and these bodies are called *chloroplasts*.

A good place to see chloroplasts

is in the leaf cells of a delicate trailing moss called *Mnium* (nī'um) which grows in shady places along streams and in damp ravines. If you will examine a leaf of this moss under a microscope you will find that it is composed of a single layer of cells. Embedded in

the cytoplasm of the cell you will see the oval green chloroplasts. The chloroplasts contain the chlorophyll which makes it possible for the plant to manufacture its own food.

A second difference between plant and animal cells is that the walls of plant cells are made of cellulose while the walls of animal cells are made of albumin. The cellulose walls are stiff and help to give the plant a rigid structure which fits it to stand erect and battle with the wind. The albuminous walls are flexible and give



How cells originate. Every new cell is formed by the division of a previously existing cell.

to animal tissues a softer structure which makes it possible for an animal to bend and move about. One important difference between plants and animals is in the material of the cell wall.

Origin of cells. Where do cells come from? How do they originate? Cells arise by the division of other cells. In a hen's egg there is a single cell with a great food supply provided for it. Incubate the egg and the cell divides. The two cells divide again. On and on the dividing process goes until we have a mass of hundreds of millions of cells out of which the body of the chick is built. In the same way there is in a young seed a single cell from which all the cells of the adult plant come.

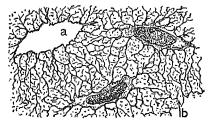
In cell division the nucleus first separates into two parts and half of it moves to either end of the cell. Then a wall is built in the cytoplasm between the halves of the nucleus, cutting the cell in two. Each half of the nucleus becomes a complete new nucleus in a new cell. Both nucleus and cytoplasm take in food and grow. When enough new protoplasm has been built the cell divides again.



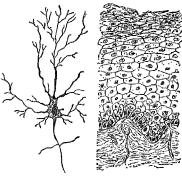
Connective tissue. In its first stage connective tissue is a group of cells which build around themselves a mass of jelly-like material, as shown in A. This material hardens into the fibers that are seen between the cells in B.



A muscle cell from the stomach. The function of the muscle cells is to cause movement.



Bone cells. These cells build a network of fibers like connective tissue and then fill the spaces between the fibers with hard mineral matter. a is a cavity from which the bone cell has been removed; b is bone material.

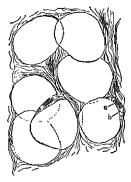


A nerve cell (left) from the surface layer of the brain. These cells are associated with thought.

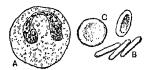
Cells of the skin's outer layer (right). These cells form a protective covering for the body. The outer cells die and dry up until they are mere scales.



Gland cells from the lining of the stomach. They secrete the gastric juice which digests the food. Many different kinds of gland cells are found in the body.



Fat cells. Food for the body is stored in these cells. Large quantities of fat collect in the cell and crowd the protoplasm (a and b) to one side. A fat cell is little more than a bag of oil.



Cells from the blood. A is a white corpuscle whose function is to kill disease germs; B is an edge view and C is a side view of the red corpuscles that carry oxygen through the body.

Some of the different types of cells found in the human body. Each is specialized for carrying on its own kind of work.

So far as we know life comes only from life. No scientist has ever created living matter from dead matter. A cell is formed only by the division of a previously existing cell. *Protoplasm is built only by protoplasm and every cell comes from a cell.*

Larger plants and animals colonies of cells. In a one-celled plant or animal, after a cell divides the two new cells separate. Each one, like Robinson Crusoe on his island, lives alone and provides for its own needs. In many-celled plants and animals the cells remain together after division. Such a group of cells may be thought of as a multitude of minute onecelled beings that live together in a great colony. Each member of the colony must have food and oxygen. Each has its own separate life. Yet all together they make up a greater living In our own bodies some cells digest the food, others take in oxygen, and others excrete the waste. The muscle cells move the body, and the bone and cartilage cells build a skeleton that Like a trained crew of men the cells all work tosupports it. They divide up the work and each does its part. In a later unit we shall study in some detail different types of cells.

Tissues, organs, and organisms. In a plant or animal body we often find cells that do the same kind of work grouped together. Such a group of cells is called a *tissue*. A tissue is a group of cells of the same kind.

An *organ* is a part of an animal or plant that does a particular work. A leaf is an organ for making food and the eye is an organ for seeing. Practically always an organ is made up of tissues of several different kinds.

An *organism* is a complete living plant or animal. It may be composed of a single cell or of millions of cells. A higher plant or animal consists of a group of organs that are organized (or put together) so as to form a complete living whole. Dead materials that come from the bodies of organisms are called *organic materials*.

Meaning of the word "cell." About 150 years ago an Englishman named Robert Hooke placed a thin section of cork under a microscope and examined it. To his surprise he found

that the cork was not one solid object. It was made up of a multitude of tiny box-like chambers. The rows of small compartments in the cork reminded their discoverer of the rows of cells in a prison or monastery; so he called them "cells." Hooke thought of the cells as empty rooms. He did not realize that each one had once contained living matter that was now dead and gone.

Later when it was discovered that all plant and animal tissues are made up of small units these units were called cells. The term is used to mean not only the wall that encloses the small compartment but also the contents of the compartment. This includes not only the protoplasm, but also in many cases stored food materials, water droplets ("cell sap"), and other substances. Think of the word "cell" as meaning not merely the wall but also the protoplasm and everything else enclosed within the cell wall. The essential part of the cell is the living protoplasm. There are cells (many protozoa, white blood corpuscles, nerve cells) that have no walls.

The cell idea is a basic one. The knowledge that all living things are built of one fundamental substance has made us understand the oneness of the living world. The cell gives us something simpler to think of than a whole complex plant or animal. With the cell idea as a key we can study the tiniest one-celled plants and animals and apply much of what we learn to all plants and animals. The quickest way to a real understanding of biology is to learn to think of all living things in terms of protoplasm and cells. All organisms are fundamentally alike in substance because they are made of protoplasm. They are basically alike in structure because in all of them the protoplasm is organized into the units we call cells.

PROBLEM TWO

What Evidence for the Unity of the Living World Do We Find in the Chemical Composition of Living Matter?

Suppose a chemist should analyze some of the protoplasm of an oyster, a rabbit, a mushroom, and an oak tree. Would he find that the protoplasm from these different organisms is composed of the same chemical materials? All living things are alike in being made up of the minute building units that we call cells. Are they also alike in that their living substance is built up of the same kind of matter? This is a chemical problem and before you try to solve it you need to have clearly in mind a few of the elementary facts that chemistry has shown us to be true about the world.

What matter is. The things about us can be touched and handled. They have weight. A stone has weight. Water has weight. Air has weight. A piece of wood or metal has weight. All these also occupy space. We can weigh them and measure them and find out how heavy and how big they are. They are made of matter. Scientists often define matter as anything that has weight and occupies space. The science that treats of the nature of matter is called chemistry.

Atoms and molecules. One of the fundamental facts discovered by chemists is that all matter is made of very small particles. These particles are so minute that they cannot be seen even with a powerful microscope, but scientists are sure of their existence. They are called *atoms* and there are 92 kinds of them, one kind for each of the 92 chemical elements. There are iron atoms, gold atoms, carbon atoms, oxygen atoms — 92 kinds of atoms in all. The atoms of each element differ from those of every other element.

Another important discovery is that in most substances the atoms are joined together in groups to make *molecules* (mŏl'e-kūls). An oxygen molecule is made up of two oxygen atoms. A water molecule is made up of one oxygen and two hydrogen atoms. A salt molecule is made up of one sodium and one chlorine atom.

A sulfuric acid molecule is a group of two hydrogen, one sulfur, and four oxygen atoms. As all the words of the English language are combinations of the 26 letters of the alphabet, so all the hundreds of thousands of substances in the world are different combinations of the 92 kinds of atoms. As a printer takes down his type and sets the letters up into new words, so the chemist breaks up molecules and recombines the atoms into molecules of other kinds.

Chemical symbols and formulas. Chemists in their scientific writing use a kind of shorthand. Instead of writing out the full names of the elements they use abbreviations which they call *symbols*. Sometimes the symbols are abbreviations of the English names of the elements, as O for oxygen, H for hydrogen, Mg for magnesium, Cl for chlorine. Sometimes they are abbreviations of the older Latin names, as Cu for copper, Hg for mercury, and Na for sodium.

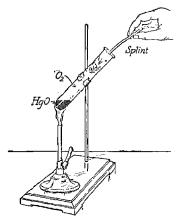
To show the composition of molecules, chemists write formulas. For example, for the molecule of water they write H_2O . This means that a molecule of water is made up of two atoms of hydrogen and one of oxygen. The formula for carbon dioxide is CO_2 , which means that the molecule consists of one atom of carbon and two of oxygen. The formula for the oxygen molecule is O_2 , for the hydrogen molecule H_2 , and for the sulfuric acid molecule H_2SO_4 .

Definition of element and compound. When all the atoms in a molecule are of the same kind the substance is an *element*. The oxygen and nitrogen of the air are elements because only one kind of atom is found in each of their molecules. Iron and tin are elements for the same reason. An element is a substance that does not break up into simpler substances.

A compound is a substance that has more than one kind of atom in its molecules. Water is a compound with molecules made of two atoms of hydrogen and one of oxygen. A compound is a substance that can be broken up into simpler substances.

Forming a compound out of elements. Magnesium is a light metal looking like aluminum or zinc. It is an ele-

ment. This means that it contains only magnesium atoms. Hold a small piece of it with forceps and touch it to a flame; it will burn with a brilliant white light. Then the metal is gone and a white powder is left in its place. Chemists indicate what happens in the above change by writing a *chemical equation* thus:



Breaking mercuric oxide into mercury and oxygen.

What has happened? The oxygen atoms of the air have united with the magnesium atoms. The

with the magnesium atoms. The white powder is a compound, magnesium oxide. Each of its molecules is composed of one atom of oxygen and one of magnesium. The ash contains all the magnesium atoms that were in the piece of metal plus the oxygen atoms from the air that have united with them.

Breaking a compound into its elements. Chemists can break up magnesium oxide and get the magnesium and oxygen apart. It is perhaps too difficult a process for you, but you can easily break up the oxide of another metal. If you will arrange a test tube containing some red oxide of mercury, as shown in the figure above, and heat it you will decompose the molecules of the compound into two elements, oxygen and mercury. The oxygen will pass off into the air, as can be proved by thrusting a glowing wood splinter into the mouth of the test tube and watching it burst into flame. The liquid mercury will collect on the sides of the test tube. Thus you will have broken up the red oxide of mercury into its elements, oxygen and mercury, neither of which is anything like the chemical compound from which it came. The equation for the breaking up of the oxide of mercury is:

$$\begin{array}{ccc} HgO & \xrightarrow{\hspace{1cm} \longrightarrow \hspace{1cm}} Hg & + & O \\ \text{oxide of yields mercury} & + & \text{oxygen} \\ \text{mercury} & \end{array}$$

Chemical and physical changes. A change in matter in which the molecules are broken up or the atoms enter into new combinations is called a *chemical change*. In such a change the atoms taking part in the action join in new combinations. They are not destroyed but merely leave their old partners and take up with new ones. In a chemical change new substances are formed. There is a change in the make-up of the molecules.

A chemical change is different from the kind of change that takes place when water freezes or turns to steam, or sugar dissolves in water. These are *physical changes*, and in them molecules do not break up. After liquid water changes to a gas (steam) or to a solid (ice) the molecules are still water molecules. After a physical change the original molecules of the substance remain intact, but after a chemical change new kinds of molecules are present.

Law of conservation of matter. Matter cannot be created out of nothing. The only way a piece of matter can increase in weight is by adding atoms of the same or of a different kind to itself. When iron rusts it gains in weight, but the gain is not evidence that new matter has been created. It shows rather that other atoms have united with the iron atoms. In chemical changes there is no creation of new atoms but only a shifting about of atoms.

Neither can matter be destroyed. The only way a piece of matter can lose weight is by losing some of its atoms. When a candle burns it disappears, but its atoms have not been destroyed. They have gone off into the air in the form of water and carbon dioxide. If you could catch all the matter given off into the air as the candle burns and weigh it, you would find that its weight is greater than that of the unburned candle. Its total weight is exactly equal to that of the original candle plus the weight of the atoms of the invisible oxygen that combined with the candle in the burning process. The law of the conservation of matter is that matter cannot be either created or destroyed.

¹ This statement and the law of the conservation of energy given on page 118 are intended to apply only in ordinary chemical reactions and in the usual transformations of energy. The newer physics has shown that matter may be transformed into radiant energy, but this idea need not concern us here.



J. Horace Mackarland

The protoplasm of the sheep, the trees, the grass, and of all other plants and animals has practically the same chemical composition. In the kind of atoms used to build the living substance there is unity in the world of life.

Composition of protoplasm. When we apply our chemistry to the analysis of living matter we find first of all that protoplasm is made of only a few kinds of very common atoms. The molecules of all protoplasm are made chiefly of atoms of carbon, hydrogen, oxygen, nitrogen, and sulfur. Often the protoplasm molecule has built into it also a few atoms of phosphorus, iron, calcium, magnesium, or other elements. Yet in its chemical composition protoplasm through the whole living world is practically the same and there are no kinds of atoms in living matter that are not in dead matter. The very same atoms that are now in dead food may soon help to make up living protoplasm and the atoms that today are a part of a living cell may quickly be passing out of it in dead wastes. The secret of life and growth is not in the kind of atoms of which the living substance is composed.

Conservation of matter in the living world. The law of the conservation of matter applies in the living world in exactly the same way as in the non-living world. Matter is not created or destroyed by living things; foods merely undergo chemical changes within the cells. When sugar is caten it unites with oxygen and its atoms pass out of the body in molecules of carbon dioxide and water that are given off. A growing animal or plant gains in weight not because it creates new matter but because it takes in atoms from the outside and builds them into its tissues. When the income and the outgo of matter in a living organism are equal the weight remains the same. When more matter is lost than is taken in the weight is decreased. As the water of a whirlpool is constantly changing, so the matter of living things is never the same. Yet there is no creation or destruction of matter when the dead materials of the food become transformed into living protoplasm or when a molecule of protoplasm loses its life spark and joins the world of the dead.

We see now at the conclusion of our problem that in the chemical composition of their living substance all plants and animals are similar. In all of them the protoplasm is built of the same few kinds of common atoms. The law of the conservation of matter holds uniformly in living organisms. We conclude that in the composition of the living substance there is a fundamental unity among all living things.

PROBLEM THREE

What Uniformity Is There in the Method by Which Living Things Obtain Their Energy?

A stone at constant temperature neither gives off nor takes in energy. It is dead. It might lie for ages with its energy content unchanged. Living things, in contrast, live and change and move. Flowers bloom, fruits form, a bird sings, a deer runs across a meadow, man goes about his daily work. An organism generates warmth, grows, and repairs its tissue wastes. In the processes and activities of life, work is done — energy is expended. A living thing must have an energy income. What is energy?

What energy is. Heat, light, and electricity are forms of energy. Radio waves are energy. A moving body has energy. Energy is entirely different from matter. We cannot lift it with our hands. We cannot weigh it or measure it by the quart or peck. Energy is the capacity or power to do work. Energy is not matter itself but the capacity to move matter or to cause changes in matter. It manifests itself to us in numerous ways and in different forms.

Be sure that you have clear the distinction between matter and energy. Matter is the stuff of which things are made. It is energy that sets matter in motion, changes its motion, heats it, changes a solid to a liquid or a liquid to a gas. The study of energy is called *physics*. Physics is the branch of science which treats of the nature and forms of energy and of the effects of energy on matter.

Transformation and conservation of energy. One outstanding fact concerning energy is that one form of it may be transformed or changed into another form. The light from the sun falling on the earth is turned into heat. The energy of motion in a swinging hammer may be changed into heat, as you can show by pounding a nail. Falling water or steam may set an electric generator in motion; the energy of motion may be transformed into electricity; electric energy may be transformed in a stove or lamp into heat or light. All about you both in nature and

in the devices made by man changes of energy from one form to another are going on. The energy of a mountain stream dashing downward toward the sea came to the earth as light from the sun.

As a consequence of careful observations and measurements of energy transformations, scientists have reached a most important general conclusion about energy. Briefly stated, it is that the total amount of energy in the universe remains unchanged. This means that when one form of energy is expended in doing work it does not disappear but is merely transformed or changed into another form. It means that energy cannot be either created or destroyed. This great conclusion is known as the law of the conservation of energy.

Storage of energy. Energy can be in a latent or inactive form. It can be stored. There is energy in a stretched rubber band, a wound-up spring, a lifted weight, or a body charged with electricity. There is energy in water that can be allowed to drop to a lower level. Great supplies of energy are stored in the molecules of chemical substances and this source of energy is constantly drawn on by us. It is the energy that is stored in molecules of gasoline that drives our cars. The energy stored in dynamite, suddenly released, causes the explosion. The energy in fuels supplies us with heat. Energy is stored in food molecules and it is this energy that is used by living things. When we eat we take in a supply of energy as well as a supply of matter for our cells. Energy stored in molecules is spoken of as chemical energy.

How energy is acquired. When a rubber band is stretched work is done on it. The band acquires the energy that was used in doing the work and this energy will cause the band to snap back to its former condition. If you lift a stone and hold it aloft the stone acquires the energy you used in the work of lifting it. Drop it and the energy of the stone becomes active and manifests itself in the way the stone falls and the force with which it strikes. An important idea is that when work is done on a body that body acquires the capacity to do an equal amount of work in returning to its original condition or position. When work is done on a body the body acquires energy.

In some chemical changes energy is absorbed. The materials must be heated or energy from the outside must be applied in some other way to bring the changes about. In such changes work is done in building the atoms into the combinations and arrangements that they have in the new molecules and the energy used in doing this work is stored in the molecules. This energy can be converted into heat, light, or other forms of energy by a chemical change in which the molecules are broken down and their atoms united with other substances. When we burn wood or coal or use food in our bodies we are releasing and transforming the energy that was in the fuel or food molecules.

Oxidation. The most familiar chemical process by which energy is released from molecules is *oxidation*, or the uniting of substances with oxygen. It is by oxidation that the energy of gasoline is made active in a motor and the energy of coal is converted to heat. It is by oxidation that the energy stored in food molecules is transformed and made to operate the life machine.

Oxidation may be fast or slow. Sometimes, as when wood burns, it goes on so rapidly that light as well as heat is given off. Then we say the substance that is being oxidized burns. In other oxidations, as when iron rusts or wood decays, the process is slow and all the energy is given off in the form of heat. Usually in these slow oxidations we do not notice the energy changes, but in them heat is released. The same amount of energy is given off by a log whether it rots in the woods or is burned in a fire.

Oxidation within the cells. After food molecules and oxygen molecules have been taken into the cells the food atoms and oxygen atoms unite. This process is called *respiration*.¹ It is a process of slow oxidation carried on within the cells and from the process the cells secure their energy. Just as in a fire the energy of the fuel molecules is transformed into heat and light, so in respiration the energy of the food molecules is transformed and

¹ The term "respiration" has two additional meanings. It is used to denote the breathing process of the larger land animals and also the taking in of oxygen and the giving off of carbon dioxide by the cell. In this problem the term is used to mean the oxidative processes that go on within the cells and furnish the energy for the life processes.

made available for carrying on the processes of the living organism. Your body is warmed by energy taken into it in food and converted in respiration into heat. Your heart beats by energy furnished by food oxidized within its muscle cells. It takes energy to think and this energy comes from food molecules oxidized within the protoplasm of the brain. Cut off from an organism either the food or the oxygen supply so that respiration cannot be carried on and the life of the organism comes to an end.

Respiration a universal life process. Allliving things — all living cells — get their energy by respiration. A one-celled animal in a roadside pool takes in tiny bacteria as food. It digests them (breaks them down into molecules). Then oxygen is united with the food and in the process the little animal secures the energy necessary for its life. Similarly a larger animal eats food, digests it, and distributes it by the blood to every body part. It takes in oxygen and distributes it through the body and the food and oxygen molecules meet in the cells. Oxidation follows and energy is given to the protoplasm. The animal lives by means of tiny "fires" burning in each of its living cells.

And plants also get their energy through respiration. They use the same food as animals and oxidize it in the same way. The same food that keeps a leaf alive might send a bird across the sky. Plants and animals differ in the way they obtain their food, but in the way they use it they are alike. Respiration is carried on by all living things.

Products of respiration. Burning coal in a furnace produces gases and ashes that must be removed. Similarly the process of respiration produces waste products that must be eliminated. Matter is taken into the cell in the form of food and oxygen. It leaves the cell as carbon dioxide, water, urea, and other wastes. In a later unit we shall study in some detail the chemical changes that matter undergoes in the life processes. For the present we shall content ourselves with the general idea that the food not used in growth or tissue repair is oxidized in the cells and that the atoms of which the oxidized food is composed leave the body in the molecules of the cell wastes. Our fuel foods

are valuable to us not for the matter that is in them but because of the energy they furnish to run the life machine.

Causes of chemical action in living things. What causes the chemical changes that go on in living things? Why do the foods within the cells of a plant or an animal unite with oxygen? Sugar does not unite with oxygen when we set it out on a table. Why should it do so in our muscle cells?

One way of causing chemical change is through the action of catalysts, and not only the oxidation of foods but all the other chemical reactions in living things are supposed to be produced in this way. A simple experiment will show a catalyst at work.

Support, as is shown on page 113, a test tube containing some potassium chlorate. Heat until the chlorate is just melted and test with a glowing splint for oxygen. Add a little powdered manganese dioxide and test again. In spite of the fact that the test tube is cooling, oxygen is now given off. The manganese dioxide is not itself changed, but it causes a change in the potassium chlorate. A substance that causes a chemical change without itself being changed is called a catalyst.

Chemists are acquainted with many catalysts. When ammonia is made from the nitrogen of the air a metal catalyst is used to cause the nitrogen to unite with hydrogen. In the laboratory, when oxygen is prepared from potassium chlorate, manganese dioxide is added to speed up the decomposition of the chlorate.

The catalysts found in living plants and animals are called enzymes (ĕn'zīms). They are substances built by the protoplasm itself. All living things produce them. In our digestive juices we have enzymes for breaking down (digesting) the molecules of starch, sugar, fats, and proteins. Inside the cells are enzymes which cause the food and oxygen molecules to unite. A yeast plant produces an enzyme that splits sugar molecules into alcohol, water, and carbon dioxide molecules. It is the activity of the enzymes that causes protoplasm to live and grow.

We have now found another line of evidence for the idea that there is unity through the world of life. The chemical process that supplies the life energy is the same in all living things. All plants and all animals get their energy by oxidizing food; the fundamental life process of all protoplasm is the same. Moreover, in all organisms chemical changes are brought about by the same means — by catalysts called enzymes, built by the organisms themselves. There are wide differences in living things, but they are all alike in this fundamental way.

PROBLEM FOUR

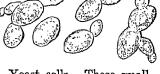
What Uniformity Do We Find in the Way Living Things Reproduce?

Every plant or animal form that continues to live on the earth must leave offspring or, like a fire that burns out, that line of protoplasm dies away. As in a relay race the baton is handed on from runner to runner, so is the torch of life passed from generation to generation in the reproductive process. In our present brief study of this process we shall use only plant materials, but animals could have been used equally well. In all living things the process is fundamentally the same.

THE YEAST PLANT

Suppose we add a little sugar to some tap water or to water from a well or a spring. Then we crumble a small amount of yeast cake into the water and set the vessel in a warm place for a day. Bubbles of gas will appear in the solution. This is carbon dioxide formed from the sugar.

Now if you will put a drop of the liquid under the microscope you will see tiny bodies like bubbles in the liquid. These are the yeast plants. They are colorless (lack chlorophyll) and live on food materials which they absorb from the solution.



Yeast cells. These small plants reproduce by budding.

A yeast plant consists of a single oval-shaped cell, but many of those you see will be growing and multiplying. A bud (sometimes more than one bud) begins to push out from the side of a cell. More protoplasm is built and the bud increases in size. Finally the bud separates from the parent plant and there are two yeast plants. This is reproduction in a very simple way — a new plant arises by growth and separation from the old one. Many small organisms reproduce in essentially the same way as the yeast plant. They simply grow and divide.

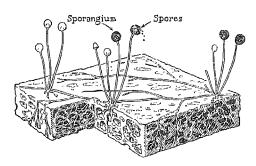


Diagram of the way bread mold grows on a slice of bread.

THE BREAD MOLD

Place a slice of bread over water in a covered dish. In a few days you will find spots of mold on the bread. In the moist air the mold flourishes and grows rapidly. Soon the bread is buried in a cobwebby mass which is made up of hundreds of thread-like filaments. This tangle of filaments is the body of the mold.

Reproduction in bread mold. If you will keep watching your mold garden you will soon see filaments growing up or out like little stalks from the mass and then tiny swellings or knobs appear on the ends of these filaments. What is happening? The mold is preparing to reproduce itself. It cannot go on growing forever on the bread. Its life will soon be spent and it is arranging to start new plants that will carry on the race.

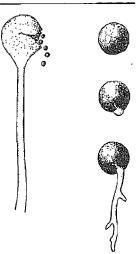
The swollen tip of a filament is called a *sporangium* (spo-răn'jĭ-um; plural *sporangia*). Examine under a microscope some of the black material from a sporangium and you will find it consists of a multitude of tiny particles. These particles are *spores*. Each one is a cell. Each one has a nucleus and cytoplasm and is enclosed by a tough wall that protects it from drying. Each spore can germinate — can burst its wall and send out a little filament that will grow and branch on and on until it becomes a mass of filaments. The spores are produced by the millions and their function is to reproduce and multiply the plant.

Formation and distribution of spores. In the sporangia the spores develop in a simple way. The protoplasm merely divides into very small cells, each one enclosed with a protecting wall. You have seen a plant started from a "cutting," or piece of another plant. The mold makes millions of one-celled microscopic cuttings — tiny pieces of itself — and scatters them forth on the chance that some of them will reach places where they can develop into new mold plants. spores blow about everywhere in the air and wherever there is a place favorable to their growth some of them are likely to fall. The mold that grew on the bread in your culture started from spores blown from some other mold plant.

SPIROGYRA

In fresh-water ponds and small lakes you will find floating masses of green material. These are the "pond scums." They belong among the green algae (see page 995). *Spirogyra* (spī'ro-jī'ra) is one of the most abundant of them. Find a mass of pond scum that has a slippery feeling and you will probably have Spirogyra.

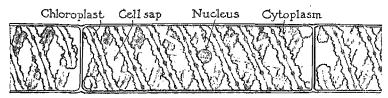
The Spirogyra plant. A mass of Spirogyra is a tangle of green filaments, each of which is a separate plant. When you put it under a microscope you will see that a filament is made up of long cylindrical cells placed



Sporangium and germinating spore of bread mold. Each spore is a single cell that can grow into a new plant.



Spirogyra filaments photographed through a microscope.



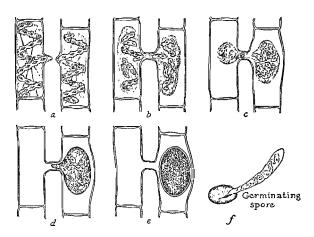
A Spirogyra cell. Much of the interior of the cell is occupied by the cell sap, which is not alive but is merely water with minerals and other substances dissolved in it. The cytoplasm lines the cell wall and strands of it extend to the nucleus, which is in the center of the cell.

end to end. You can readily recognize the plant by the large green ribbon-like chloroplasts that are wound around like spirals in the long cells. In some kinds of Spirogyra there is only one chloroplast in each cell; other kinds have two, three, four, or up to sixteen chloroplasts. *Spirogyra* is a genus and the many different species differ in size and in the number of chloroplasts in the cell.

Reproduction in Spirogyra. Spirogyra reproduces by spores, but these are not formed as they are in the bread mold. They are formed by the union of cells and not by cell division. As two filaments lie side by side in the water, little swellings or beaks begin to grow out from the sides of the cells of each filament toward the cells of the other filament. The two beaks continue their growth until they come together (see the figure on page 127). Then the walls between them break down, leaving a small crosswise tube connecting the two cells.

While this is happening the living material of each cell is rounding itself up and when the tube is complete the contents of one cell pass over into the other cell. Here the two masses of protoplasm are fused. Cytoplasm unites with cytoplasm and nucleus with nucleus — the protoplasm of two cells is blended into that of one. Then the fused mass of protoplasm builds a thick wall about itself and a spore has been formed.

Each pair of cells in the two filaments of Spirogyra may make such a spore. The spores are released by the decay of the cell walls of the filament and after their release they sink to the bottom of the pond or pool. There they rest until a favorable time for



Reproduction in Spirogyra. A connection is formed between two cells, and the protoplasm of one flows over into the other. Then the two masses of protoplasm unite and a heavy wall comes about the spore that is thus formed. In time the spore germinates and forms a new plant.

growth comes. Then they germinate and grow into new Spirogyra plants.

Each new plant that grows from a Spirogyra spore has two parents. Its protoplasm is a blend or mixture of the protoplasm of two previous plants. The cell from which it starts was formed by cell fusion and not by cell division as in the bread mold. The process by which the two Spirogyra cells unite is called *conjugation*.

Some useful definitions. A *spore* is a reproductive cell. By a reproductive cell we mean one that can grow into a new plant or animal.

A gamete (găm'ēt) is a sexual cell. By a sexual cell we mean one that can unite with another and form a cell that can grow into a new plant or animal. The cells that unite in Spirogyra are gametes.

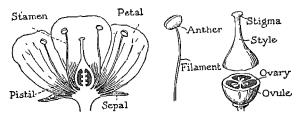
Asexual reproduction is reproduction without sex. In asexual reproduction the reproductive cells are formed by cell division. The kinds of reproduction that we studied in yeast and in the bread

mold are asexual. The spores of the bread mold are asexual spores.

Sexual reproduction is reproduction by the union of gametes, or sexual cells. In sexual reproduction the reproductive cells are formed by cell fusion. Two cells are united and a new organism grows from this fused product. The formation of spores in Spirogyra by conjugation is an example of sexual reproduction.

REPRODUCTION IN FLOWERING PLANTS

In higher plants reproduction is by seeds, and seed formation is connected with flowers. We shall therefore begin our study of reproduction in these plants with the examination of a flower.



Parts of a flower.

Parts of a flower. A typical flower has the parts shown in the figure above. At the base of the flower on the outside are the green *sepals* (sē'pals), which taken together make up the *calyx* (kā'lĭks). Then come the colored parts which are called *petals* and together form the *corolla* (ko-rŏl'a).

Inside the corolla are the *stamens*, each made up of a *filament* (or stalk) and an *anther* at the top of the filament.

In the center of the flower is the *pistil*, which has three parts: at the bottom is the *ovary*; rising from the ovary is the long *style*; and on the tip of the style is the *stigma*.

There are many variations in flowers. In some the sepals as well as the petals are colored. The sepals and petals may be joined together instead of separate. There may be several or many pistils in place of one. The stamens and pistils are the "essential" parts of the flower. The flowers of grasses and of

many trees lack the calyx and the showy corolla but they have stamens and pistils, which must be present for the reproductive process to be carried on.

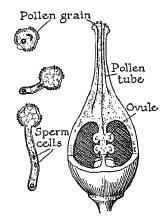
Union of the gametes. In the lower part of the pistil (ovary) rows of little *ovules*, or young seeds, are developed. Inside each of these is a large cell that is called the *egg*. This is the female cell, or female gamete. It corresponds to the egg laid by a female fish or frog in the water.

In the anthers at the tops of the stamens a yellowish and usually powdery substance is produced. This is the *pollen* (pŏl'en). Examine pollen under a microscope and you will find that it is composed of small grains. Each tiny pollen grain is filled with living protoplasm. It can germinate and start growth quite like the spore of the bread mold.

If a pollen grain gets on the stigma of the pistil it sends out a little tube which grows downward through the style. The grain

itself stays up on top of the stigma, but the tube pushes downward through the tissue of the style and the protoplasm of the pollen grain moves downward inside the tube. On and on the tube grows. Finally it reaches the ovule, pushes into it, and comes to the egg. Then the end of the tube opens and a small cell consisting of a nucleus with a little cytoplasm about it is discharged. This is the sperm. It is the male cell, or male gamete. It unites with the egg and the egg is then said to be fertilized.

In fertilization, as in the conjugation of the gametes of Spirogyra, two cells are united into one. The only real difference is that in Spirogyra the two gametes are the same size,



Fertilization of the egg in a flowering plant. The pollen tube grows down through the pistil until it reaches the egg within the ovule. Then a sperm discharged from the pollen tube unites with the egg. The union of the egg and sperm is called fertilization.

while in the flowering plant one is large and one is small. In the higher plants as in the higher animals the sex cells have been differentiated into male and female — sperm and egg. When the gametes are the same size the process of union is called conjugation, and when they are of different sizes it is called fertilization. In essence conjugation and fertilization are the same.

After fertilization the egg in the ovule begins growth, divides, and develops into a new plant. At the same time a rich store of food accumulates about it and a hard protective seed coat is developed. In a dry seed you will find a baby plant resting in the midst of its food supply.

A fact to be emphasized in connection with this study is that through the whole biological realm the reproductive process is fundamentally the same. Whether reproduction is sexual or asexual there is no break in the life chain between generations. All plants and all animals produce offspring by a continuation of the life of the parent cells. New plants and new animals are not produced by the creation of life anew but by the growth and multiplication of cells that are already alive.

PROBLEM FIVE

What Evidence for the Kinship of Living Organisms Do We Find in Their Growth and Development?

An organism both grows and grows up. It increases in size, and as it does this it takes its own special form. In its early stages a developing plant or animal is called an *embryo*. Study of the changes it goes through in early life is called *embryology*.

Growth. All living things have the ability to grow. The protoplasm of each one of them can build more protoplasm of its own kind. This process may go on very rapidly. Some bacteria in a good nutrient solution can double their size and divide in ten minutes, and when a chick begins its growth the single cell in the egg quickly increases to a multitude. One of the fundamental ways in which all living things are alike is in their possession of the power of growth.

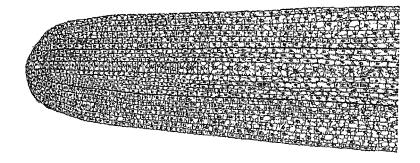
Developmental changes. In a one-celled organism like Pleurococcus or yeast the developmental changes are very simple. The single cell of which the organism is composed lives alone. It gets its own food, takes in the oxygen it needs, and gets rid of its wastes. It has no special organs or tissues and in its development simply grows until it reaches full size.

With a large and complex plant or animal the situation is very different. Most of its cells are buried in the mass where they have no chance to obtain food or oxygen for themselves or to supply their other needs. There must be arrangements for the transportation of food, oxygen, and water within the body and for the removal of wastes. There must be tissues and organs for many kinds of work and a system of control of all the body parts. As the organism grows it not only increases in size but also becomes fitted for its more complicated life by a specialization of its cells. The cells become differentiated (or different from each other) and form tissues and organs that are suited for different kinds of work. Great changes go on in a complex organism as it grows and takes its adult form.

How cells become differentiated. In its early life a chick is a single cell within the egg. A plant such as a tree or one of the flowers of the garden begins as a single cell within a developing seed. In both chick and plant the cell grows and multiplies and soon becomes a small group of cells. Each cell is a soft mass of protoplasm with a nucleus and cytoplasm. All of them are much alike.

Then as growth continues cell differentiation begins. In the chick some cells grow into long muscle fibers, some become nerve cells, some bone cells, some gland cells. In the plant some of the cells change to strong wood fibers, some to vessels for conducting food and water, some form an outside protective coat. By and by we find that the chick has become a collection of animal tissues and organs fitted to live together in the animal way. We find that the plant has many different tissues fashioned into roots, stem, and leaves, all fitted to live together in the plant way.

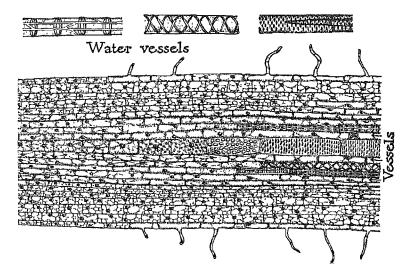
In the higher forms of life the cells become specialized for coöperative life. Some are fitted for one kind of work and some for other kinds. They are built into different tissues and organs,



Cell differentiation in a root tip. At the tip where the cells are young they are all much alike. Farther back in the root they differentiate, or become different. Some of the cells develop into root hairs. Some are transformed into vessels.

each of which has some particular function. Just as in our human society we have carpenters, bricklayers, plumbers, automobile mechanics, and other workmen, each trained to do his own kind of work, so in the body of a complex plant or animal we have cells fitted for very different tasks. The muscle cells move the body, the cells of the digestive glands build enzymes that digest the foods, the skin cells protect the body, and the kidney cells excrete wastes. By differentiation each kind of cell becomes fitted to do its own special work.

Individual development repeats race history. When the embryology of the various living things about us is studied many curious facts are learned. At one stage the embryo of the chick or the pig develops gill slits in the side of the neck. A butterfly at one period of its life is worm-like in form. The embryo of the oyster is a little swimming collection of cells and a young crab is a big-eyed creature quite unlike its parents in form. Until comparatively recently no explanation could be offered for such facts; now one has been found that is a powerful argument for the common origin of living things.



All the various tissues that are found farther back in the root are formed by the cells becoming different.



A bean plant. The first two leaves are different from the later leaves.

Biologists believe that in its development an individual plant or animal repeats in a greatly shortened way the history of its race. The theory is that the individual in its early growth goes through the same changes that its ancestors went through in the geologic ages of the past. Each individual plant or animal begins as a single cell and then it is supposed to go by the same route its remote ancestors followed, to the mature form. The presence in the early life stages of structures that quickly disappear or are altered is interpreted as evidence of descent from ancestors that had these structures.

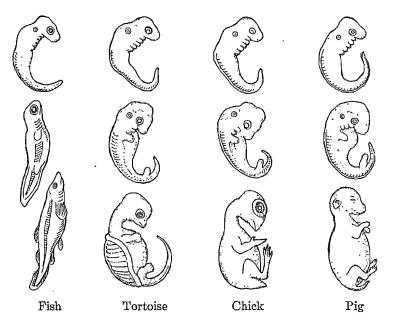
Examples to support the theory. Of course a developing plant or animal that goes through in a few days — sometimes even in a few hours — changes that occupied its ancestors for millions of years must often short-cut and omit. An hour-by-hour study of very young embryos is required before the theory can be fully appreciated. Yet you can see about you many examples of young plants and animals going through marked changes as they mature.

A bean seedling has a simple leaf and not the compound leaf of the mature bean plant. This fact, according to the theory, shows that beans had simple-leaved ancestors. A young robin has a speckled breast. This presumably shows speckle-breasted ancestors. A chick embryo at one stage has a long tail. This indicates a tailed ancestor. The egg of a toad hatches in water and grows into a tadpole that has a tail and gills. Then the tadpole loses its tail and gills, develops lungs and legs, and comes out on land. This life history shows that the toads sprang from a water stock. In many animals the most striking changes take place before the young are born or hatched, but in the toad and in plants the entire life history unfolds before our eyes.

The theory that the early stages in the development of an

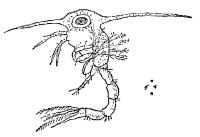
animal show its ancestry and relationships was applied in the classification of the barnacles. These are queer animals that cling to ships and ocean rocks and wharf piles as well as to turtles, fishes, and the snakes of tropical seas. They seem to have shells, but they are unlike mollusks and for a long time no one could decide to what group of animals they belong. Finally eggs were secured and hatched. The young proved to be like little crustaceans. At first they swam freely about; then they settled down and developed into the strange adult barnacles. The barnacle is now accepted as a crustacean on the evidence of its form in the early stages of its life. It is believed that its ancestors were once free-swimming crustaceans and that its adult form is an adaptation to life in the moving waters of waves and tides that bring to it its food.

The theory that each individual in its development repeats the stages its ancestors went through in the development of the



Vertebrate embryos. In the early stages they are much alike, but as they develop they become more and more different. In its development each is supposed to repeat the history of its race.

race is called the *recapitulation theory*; sometimes it is spoken of as the *biogenetic law*. In your reading you may find reference to it under these names. Psychologists have applied the theory in interpreting the instinctive development of children, holding that various ages represent different stages in the rise of the human race.



Nature Magazine

A young crab, very different in appearance from the adult animal. The small dots to the right indicate the actual size of the organism.

Taken in their entirety the changes in size, in form, and in structure that organisms undergo in their growth and development are interpreted as meaning that all living things are akin. In their adult stages organisms may seem very different, but they all start life as a single cell and it is believed that they

all have a common ancestry and trace back to one simple life form. In the facts of growth and development scientists find what they consider very convincing evidence for the oneness of the world of life.

THE ARGUMENT IN BRIEF

The world of life, notwithstanding the many types of organisms found in it and the great differences in them, is one whole. We miss the deeper understanding of this world if we allow the diversity in it to keep us from seeing its unity.

All living things are composed of protoplasm. In this substance, and in it alone, life resides. Protoplasm increases in amount (grows) by building dead material into the same substance as itself and endowing it with life. New organisms are produced by the growth of a portion of protoplasm that has been separated from the parent organism.

Protoplasm is organized into microscopic units called cells. Each of these is a marvelous laboratory in which every function essential to life is carried on. The cell takes in food and oxygen. Within the cell the food and oxygen unite. The process is called respiration. In the process the energy is released which is life or results in life — whatever life may be. All living things require the same materials for the growth and repair of their protoplasm. All of them secure the energy for their life processes in the same way. All of them reproduce in fundamentally the same way. In the growth and development of complex and diverse forms from single cells there is much evidence for the kinship of all that are This unity through the realm of life has led even to the suggestion that we should consider all living things taken together as one great organism. The thought is that different kinds of living things differ as do the various parts of a tree, but that collectively they constitute a great being which has grown and spread its branches over the whole earth.

We ourselves are an integral part of this great biologic world. The human body is composed of cells. It is nourished and grows and develops in the same way as other animal bodies. The laws of life operate in us as they do in other living things. This is fortunate indeed for us, for it makes possible the application of much that is learned by a study of other organisms to the solution of problems of human life.

UNIT COMPREHENSION TEST

- A. Define: cell; protoplasm; nucleus; cytoplasm. Describe a typical cell. Describe Pleurococcus. Define: chlorophyll; chloroplast. What difference is there in the walls of plant and animal cells? How do cells originate? How is a multicellular (manycelled) plant or animal like a community of people? Define: tissue; organ; organism; organic materials. Why were the small living building units called cells? What in their structure shows a unity among all living things?
- B. Define: matter; atom; molecule; chemistry. What is a chemical symbol? a chemical formula? a chemical equation? Define: element; compound. How is a chemical change different from a physical change? What is the law of the conservation of matter? Is matter created or destroyed in living things? Of what elements is protoplasm chiefly built? What evidence for the unity of life is found in the chemical composition of protoplasm?
- C. How is matter distinguished from energy? What is meant by the transformation of energy? by the law of conservation of energy? by chemical energy? How do molecules acquire chemical energy? What is the most familiar method of releasing energy from molecules? How does oxidation differ from burning? How is the energy of food molecules released within the cell? What is the process by which energy is released within a cell called? Do all living things carry on respiration? What are the important products of respiration? What becomes of these products in the animal kedy? Define a catalyst and an enzyme and explain how they work. What evidence for the unity of life is found in the way living things obtain their energy?
- D. Describe the yeast plant, the bread mold, and Spirogyra, and explain how each one reproduces. Define: sporangium; spore; gamete; asexual reproduction; sexual reproduction. What are the parts of a flower? Define: calyx; corolla; filament; anther; ovary; style; stigma. What parts of the flower are essential to seed production? Tell how the pollen tube grows and the egg is fertilized in a seed plant. Define: ovule; egg; pollen; sperm; fertilization. What similarity is there in the way all living things reproduce?
- E. What is an embryo? What is embryology? What is cell differentiation and how does differentiation take place? What advantage to a large organism is there in cell differentiation? What is the recapitulation theory? What are examples that support this theory? How are developmental changes in higher animals and plants interpreted as evidence for the unity of the living world?

SUGGESTED ACTIVITIES AND APPLICATIONS

1. Under a microscope examine for cell study:

The skin of an onion or of the lower epidermis of a geranium leaf; loose cells from the inside of the cheek; a thin moss leaf; sections of a root tip or of liver or other animal tissue prepared for microscopic examination. The nucleus and cytoplasm are best seen in the prepared slides, which have been colored ("stained") to show the different cell parts. By using a little dilute aqueous iodin solution the nucleus in some of the other cells is made more easily visible.

Draw a few cells, showing their shapes and labeling the cell parts. Draw cells from a moss leaf, showing the chloroplasts.

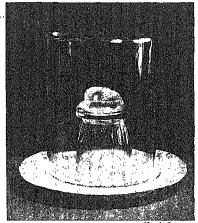
2. Examine Pleurococcus under the microscope. The entire cell appears green because of the large single chloroplast.

Draw a single cell and groups of two or more cells.

Examine a prepared slide of a root tip and see if you can find evidence of cell division. How are new cells produced?

- 3. Perform the experiments indicated on pages 113 and 121.
- 4. Examine yeast plants under the microscope. Draw several of them. How does yeast reproduce?
- 5. Make a bread-mold culture in the manner indicated in the illustration. Water should be kept in the plate so that the atmosphere within the vessel will be moist. It will be well if each student will make a culture for himself at home so that he may have better opportunities to observe it. The mold can be grown in any covered vessel.

With a reading glass or hand lens examine the mold. The body is made up of a mass of filaments from which short vertical filaments arise bearing sporangia on their ends. At intervals from a fila-



Hugh Spencer

ment, branching root-like growths strike downward into the bread as roots develop from the runner of a strawberry plant (page 237).

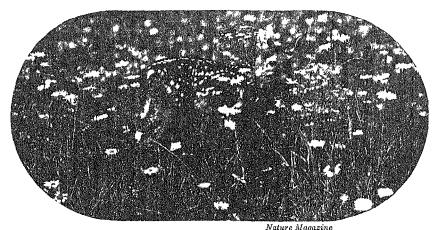
Examine the filaments, sporangia, and spores of the mold under a microscope. Draw a sporangium in different stages of its development. Draw a spore. Place a drop of gelatin on a slide. Inoculate with mold spores. Keep in a moist atmosphere and examine for spore germination. 6. Examine living Spirogyra filaments.

From conjugating material either fresh or preserved, or from prepared slides, make a series of drawings showing the formation of a spore by conjugation.

7. Examine a flower (e.g., snapdragon, geranium, gladiolus) and identify the parts. Diagram the parts in a manner similar to that employed on page 128.

Place pollen grains in test tubes containing sugar solutions ranging in strength from 2 per cent to 5 per cent and examine to see if the grains germinate and send out pollen tubes. Boiling the solution before the cultures are started will help keep down bacterial growth.

8. In a flat shallow box or wide pan plant a number of kinds of flower seeds. Note the young plants and also any weeds that appear. Are the first leaves of the plants like the ones that appear later? If young pines and cedars are available, examine their leaves and compare them with the adult leaf form.



9. The adult Virginia deer (white-tailed deer) is solid in color, but the young are spotted as is shown in the photograph above. Account for the spots of the young.

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New York Association of Biology Teachers. Adventures in Biology. (50 cents.)
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New York; 1940. A list of 250 briefly described tested projects for interested
individual students and groups to carry out.

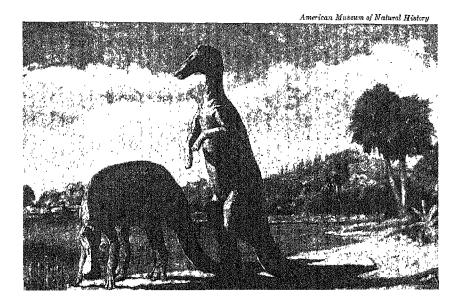
UNIT 4

CHANGES IN LIVING THINGS

The earth has undergone great changes and living things have changed also. The plants and animals of today are different from the plants and animals of the past.

> "Observe always that everything is the result of change, and get used to thinking that there is nothing nature loves so well as to change existing forms and make new ones similar to them."

> > MARCUS AURELIUS



A RECORD OF CHANGE

QUESTION FOR CLASS DISCUSSION

Is there any evidence that the region in which you live has ever been under water or has been covered by an ice sheet?

"There rolls the deep where grew the tree.

O earth, what changes hast thou seen!

There where the long street roars hath been
The stillness of the central sea.

The hills are shadows, and they flow
From form to form, and nothing stands;
They melt like mist, the solid lands,
Like clouds they shape themselves and go."

ALFRED LORD TENNYSON

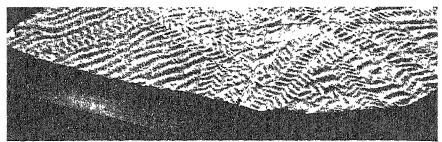
GEOLOGISTS tell us that the earth is very old, and that since its formation it has undergone great and continuous change. It is stated that areas of the earth's surface rise and fall; that a vast inland ocean once occupied the interior of North America; that our eastern coast has gone down, and that Chesapeake and Delaware bays are old river valleys now below the level of the sea; that tropical plants once grew in Greenland; and that there have been frigid ages when great ice sheets covered much of the land of the temperate zones as they cover most of Greenland and Antarctica today. The story of the world as the geologists relate it to us is a record of constant flux and change.

We are told also that the living things on the earth have changed. Scientists think that in the early days of life on our planet there were only small and simple organisms, and that as age followed age new kinds of plants and animals developed from those that had gone before. This must mean, if the idea is correct, that as protoplasm passes from generation to generation it may take new forms. It means that gradually plants and

animals may come into being that are very different from the plants and animals from which they are descended. You will need your imagination as well as your intellect while you are engaged on this unit. The subject for investigation is the history of life on the earth and the changes living things have undergone in their long procession down the years.

Problems in Unit 4

- 1 What evidence is there that the earth is very old and has undergone great changes?
- 2 What record have we of the development of the plant kingdom?
- 3 What records have we of the animals of the ancient seas?
- 4 What were some of the early land animals?
- 5 What do we know of the history of the reptiles?
- 6 What record have we of the origin of the birds?
- 7 What history have we of the development of the mammals?



U S. Natronal Museum

Sandstone showing ripple marks of 500 million years ago. The trails were made by large worms that c awled over the beach in early Paleozoic time.

PROBLEM ONE

What Evi tence Is There That the Earth Is Very Old and Has Undergone Great Changes?

No human being saw the earth when it was young. No man was present to write down a description of it or a history of the changes that took place on it. How then do we know anything about what the earth was like in earlier times? How do we know what kinds of animals and plants lived on it before the age of man? The record is in the rocks. These are the great book in which is written the story of the long ago.

In rocks we find ripples that speak of waves on ancient shores. We find tracks of animals that walked in an older time and prints of leaves that fell before man knew the earth. In mountain valleys are beds of limestone that must have been laid down deep beneath the sea, and on quiet plains stand hills that were once masses of hot, volcanic rock. On the surface of a piece of rock we may find the prints of raindrops that fell on a mudbank in an old-time storm and within the rock the trail of a worm that bored its way through the mud hundreds of millions of years ago. The rocks tell us of great things and also of many little things that happened in an ancient time.

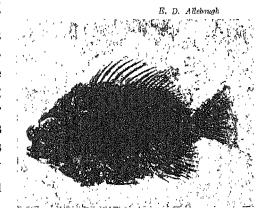
Classes of rocks. Geologists divide rocks into three great classes — igneous, sedimentary, and metamorphic.

The word "igneous" comes from the Latin *ignis*, fire. Igneous rocks are fire rocks. They are made by the cooling and hardening of hot, molten materials from deep within the earth. Granite is an example of such rock. Basalt and diabase (commonly called "trap") are other igneous rocks.

Sedimentary rocks get their name from the word "sediment." Some of them are made of materials that were dissolved in water and then deposited on the bottom of the sea. Some are composed of sand and clay washed down by streams into valleys or lakes or into the ocean and then hardened into rock. If these materials get buried deep enough in the earth and are subjected to sufficient heat and pressure they will become rock. The three most important kinds of sedimentary rocks are limestone, sandstone, and shale. The sedimentary rocks are the important ones to the biologist because they are the rocks that contain the records of the plants and animals of the past.

"Metamorphic" means metamorphosed, or changed. Metamorphic rocks are rocks that have been changed. Originally all rocks were either igneous or sedimentary, but by pressure, heat, or other agencies these rocks in many places have been greatly transformed. Marble is limestone that has been changed by heating. Slate is shale that has been under great pressure. Sandstone if it is heated and fused may cool as glassy quartzite. In igneous rocks heating may cause the formation of new chem-

ical compounds or changes in the rock structure. Most of the changes have been brought about through the rocks' having been buried deep in the earth or by hot material being shot up through them or over them. Nearly all the rocks laid down in the earlier periods



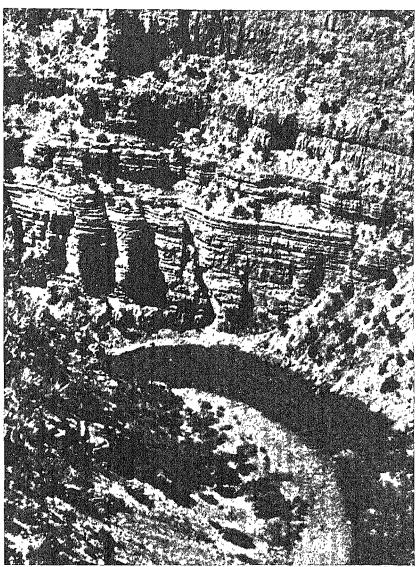
Imprint of a fish that was buried in the Silurian period.

of the earth's history have been greatly changed from their original condition.

Character and formation of sedimentary rocks. You can recognize sedimentary rocks by the fact that they lie in beds, or layers. Geologists call a rock layer a stratum (strā'tum; plural strata) and they speak of the sedimentary rocks as stratified because they are made up of strata. Limestone is deposited in the sea. Sandstone is made from beds of sand by the cementing together of the sand grains. Shale is made of deposits of clay pressed together and hardened. Usually shale can be split into thin, flat flakes, or layers. In the oceans, along coasts, and at the mouths of streams we can today find deposits of the kind from which the sedimentary rock layers were formed. Except where they have been overturned by the crumpling and folding of the earth's crust the strata of the sedimentary rocks lie one above the other in the order of their age. The oldest are at the bottom and the newest ones on top.

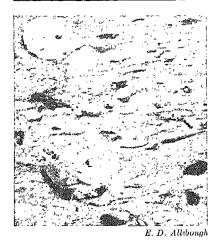
Fossils in rocks. The most interesting things that we find in rocks are the fossils. These may be the ripples made by waves on an ancient sandy beach or the pits made in soft mud by the raindrops of hundreds of millions of years ago. They may perhaps be the prints of leaves or the tracks of animals; or they may be casts or reproductions in stone of the bodies or parts of the bodies of plants and animals. Fossils are formed only in sedimentary rocks. Each one dates back to the time when the material of the rock in which it is found was soft mud or sand.

Fossils of plants and animals are formed by the body of a plant or animal becoming buried in sediment that is being deposited in a swamp, in a lake, or in the sea. As the body lies covered with the ooze it gradually becomes infiltrated with mineral matter which replaces the cells and tissues as they decay. More and more sediment is deposited and the plant or animal body is buried deeper and deeper. Finally, because of the pressure and the heat of the earth, the sediment changes to hard rock and in the rock is embedded the petrified body of the organism.



E. D. Allebough

The rocks in the center of the picture lie in layers and are therefore sedimentary rocks. They are composed of materials that were washed down and deposited in water, hardened into rock, and elevated to become again a part of the land. The same forces that have been operating through ages past are still at work on the earth today. The beds and layers of sediment that are now being deposited at the mouths of streams will be rock in a future time.



A conglomerate rock made by cementing together pebbles with finer materials. Where conglomerate rocks are found there was once a rushing stream capable of moving stones of some size.

Reading the rock book.

By studying the rocks we can learn much about what happened in the past. Limestone is formed only in the ocean; when we find it, even though it be on a mountain, it tells us that here at one time was the sea. Where we find rocks made of pebbles cemented together we know there was once a rushing stream able to carry pebbles and larger pieces of stone and we know that a rushing stream means high land. Shales show where fine particles of clay settled down in quiet waters, and sandstone where the coarser particles were dropped.

From the fossils preserved in the rocks we learn the sizes and forms of plants and animals that lived when the materials of the rock were laid down. To those who know their meaning the rocks reveal the history of the earth and of living things.

Piecing together the record. The rocks hold the story of the earth, but only a part of the record is found in any one place. It is the work of the geologist to gather together the scattered pages of the record and arrange them in the right order. To do this he must find the rock layers that were laid down in each period of the earth's history and arrange them according to their age. This the geologist attempts to do by studying the rock layers wherever they may be exposed.

In the Grand Canyon of the Colorado the stream has cut down for more than a mile to the old igneous rocks and in the canyon walls the succession of strata can be seen. Along mountains the edges of the strata are often exposed so that it is possible to see the order in which the layers were deposited. Often great beds of limestone, sandstone, or shale will extend for hundreds of

miles across a region and at their margins they join or overlap other strata. By studying all these strata and noticing how they fit together it is usually possible to tell the relative ages of the rock layers. By bringing together their knowledge of the rock layers in different parts of the earth, geologists have worked out a history of the earth that is reasonably complete.

Measurement of geologic time. We cannot in geology measure time in years. In northwestern Pennsylvania and

New Jersev there is a bed of limestone - Kittatinny (kĭt'a-tĭn'i) limestone about half a mile thick. We know that it is younger than the rock below and older than the rock above it, but we do not know its age in years. must have taken millions of years for a layer of this thickness to settle on the ocean's bed, but how many vears it took and how long it has been since the laver was finished we do In geology we not know.



Brooklyn Botanic Garden

Stumps of a coal forest uncovered near Glasgow, Scotland. They are the fossil remains of plants that grew 300 million years ago.

measure time in eras, periods, epochs, and ages — not in years. The geologist arranges a table of the different rock strata in the order of their ages. His eras and epochs are marked off by decided changes in the fossils or by evidences of changes of climate, risings and sinkings of the land, or other great happenings. If he finds thick strata he concludes that it probably took a long time to lay them down. The geologist can often guess that one period of geologic time was long or short as compared with another, but he does not know the actual length of any of them. He knows that the earth is very, very old — exactly how old he has not learned.

The earth calendar. On pages 998 and 999 is a table of the divisions of geological time. It shows the plants and animals that appeared in some of the periods and at what periods different forms were most abundant. Look the table over, but do not try to commit to memory the names of the divisions. You can use the table for reference from time to time as you desire. As you will see, the simpler plants and animals came first and as time advanced the higher animals and the flowering plants appeared. A study of the rocks shows that old-time plants and animals were different from the ones now alive. From the fossils in the rocks we learn that as age followed age new forms appeared and some of the old ones died away.

On the table there is an estimate of the length of some of the geologic periods in years. You should understand that the figures given are only guesses. They have been arrived at by calculating how long it would take to lay down sedimentary rock layers of the thickness that we find and how long it would take the waters from the land to carry into the sea the minerals it contains. In making their calculations geologists have assumed that conditions on the earth through its history have been on an average much as they are now and that in the past materials have been carried from the land to the sea at approximately the rate they are being carried now. These assumptions may or may not be correct and even if they are correct the calculations may be far from exact.

There is, however, a method of calculating the age of some rocks that has given interesting and perhaps more reliable results. There are rocks that contain small quantities of a heavy metal called uranium and of lead. The uranium slowly changes to lead and the rate of change is known. If we know the ratio of lead to uranium in a rock we can calculate how long the change has been going on. One such calculation gives the age of a piece of igneous rock from the Dakota Black Hills as 1500 million years. The ages of certain other rocks seem to be more than a billion years. Understand that these figures do not show the age of the earth. The rocks that contain the uranium are igneous ones and the

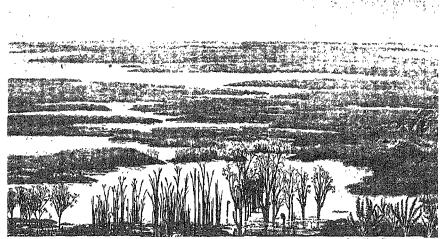
figures show only the length of time since the molten materials in these particular rocks solidified. How long the materials existed on the earth before they hardened into the rock we do not know.

Signs of early life. The earliest sedimentary rocks are greatly metamorphosed and neither plant nor animal fossils are found in them. Yet it is believed that life existed when these rocks were being laid down. There are layers of limestone among them and limestone is supposed to mean animal life in the sea. There are beds of iron in these old rocks and iron is being deposited today only under the influence of bacteria in the bottoms of bogs. There are flakes of carbon in the form of graphite scattered in these rocks and the carbon is supposed to have come from the bodies of plants and animals. Even in some of the pre-Archean (ar-kē'an) rocks, which are igneous rocks and older than the sedimentary ones, there is graphite in large amounts.

Formerly these pre-Archaean rocks were supposed to be the original "bones" of the earth sticking out, but now some geologists consider them to be sedimentary rocks that have been melted up. They believe that even when these old, old rocks were being formed there was life on the earth. The oldest true fossils are prints of sponges and certain ball-like structures supposed to be beds of algae, found in the rocks of the Archean age. Earlier beds of limestone, iron, and graphite give us reason to believe that life existed long before that time.

How old is the earth? We do not know. The oldest igneous rocks we find may have been made by melting up sedimentary ones. The oldest sedimentary rocks may have been raised as land and washed down into the sea a dozen times before the rock layers that we know were formed. Maybe the matter that is now the earth was once star dust trailing through space. If so, what went before the star dust? Maybe it was once a part of the white-hot sun. If so, what went before that?

Our trouble is that the story reads backward instead of forward and the beginning is hidden in the mists of time. In geology something always goes before.



Brooklyn Botanic Garden

A landscape of the early Devonian period. Three kinds of early land plants are shown. They were from 1 to 2 feet high, and were related to the ferns rather than to the seed plants.

PROBLEM TWO

What Record Have We of the Development of the Plant Kingdom?

The fossil record of the early plants is very fragmentary. In the rocks of the Proterozoic and of the early Paleozoic there are many animal fossils. We assume that there must have been plants to support this animal life, for green plants are the food makers of the world. Yet only a few fossils of alga-like plants have come down to us from these times. The reason for this doubtless is that the early plants were small soft-bodied water forms that left few traces of themselves in the rocks. It was only after there were land plants with hard tissues in their bodies that a fossil record of them that is at all complete was preserved.

Early land plants. The oldest fossils of land plants are found in rocks of the Silurian period. The illustration above shows some of the earliest that are known. These plants reproduced by spores and they were related to the ferns rather than

to the seed plants. They were very small and for a long time the vegetation of the land was feeble and sparse. Gradually, however, new and larger kinds of plants developed until the beautiful forests of the coal period appeared. Fossils show that the different kinds of plants of these forests developed gradually out of the smaller plants that had gone before.

Plants of the coal forests. Turn to page 996 and note the plants that belong under Phylum Pteridophyta. The three groups are the ferns, the club mosses, and the equisetums (ĕk'wĭ-sē'tums). These were the prevailing plants of the coal period. More than 3000 fossil plants from the coal measures have been classified and named and nearly all of them are pteridophytes (tĕr'ĭ-do-fīts). In coal we find not only the prints of leaves but sometimes also the forms of trunks and even stumps standing upright as they grew in the ancient swamps. Our knowledge of the coal plants is therefore remarkably complete.

The pteridophytes that are alive today are small plants, but many of those of the coal forests were of great size. The living forms are the pygmy survivors of a giant stock and to judge the size of pteridophytes by them would be like judging the size of reptiles by our snakes and lizards and not taking into account the

great dinosaurs (dī'no-sors) of the past.

Ancient club mosses. Among the most prominent of the coal plants were two types of club mosses, Sigillaria (sĭj'ĭ-lā'rĭ-a) and Lepidodendron (lĕp'ĭ-do-dĕn'dron). The Sigillarias had long, tall trunks, some of which were slightly branched. They reached an extreme height of 100 feet and a thickness of

Plants of the late Devonian period. Gradually the land plants increased in size.

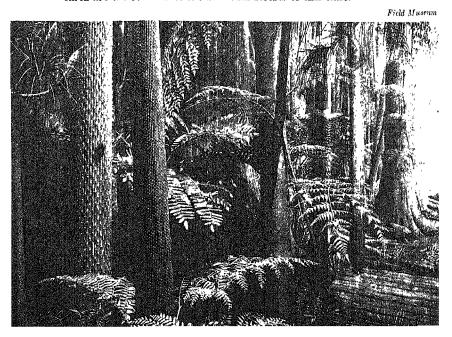


6 feet, but trunks half this height and 2 or 3 feet in diameter were more common. The other kind of these giant club mosses, the Lepidodendrons, was more branched. Both kinds had in addition to their upright stems branching prostrate ones that ran everywhere in the mud like great wide-spreading roots and held them erect in the swamps in which they grew. The club mosses have such prostrate stems today.

Equisetums and ferns. Other common plants of the coal forests were the *Calamites* (kăl'a-mī'tēz), the equisetums of that time. These plants had a jointed stem with large, soft pith. There were branches at the joints and the leaves were very small. They were of many kinds and the largest reached a height of 60 or even 100 feet and were from 1 to 3 feet in diameter. The outer part of the stem was woody and many of these stems have been preserved.

Ferns also were very abundant in the coal forests. Many of

A view in a forest of the Carboniferous period. Most of the coal beds of the earth are the remains of the beautiful forests of this time.

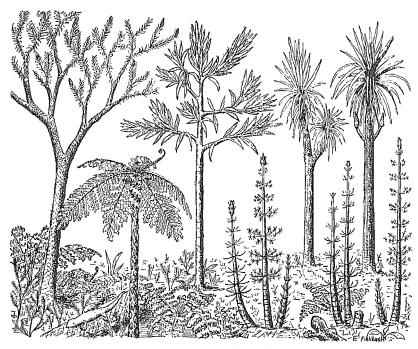


them grew upright, as the beautiful tree ferns of the tropics grow today. All of them had large leaves. In both ancient and modern times the ferns have been distinguished by their beautiful long, feathery leaves. In number of kinds, ferns were the most abundant of the coal plants. Prints of their leaves in places lie thick in the coal seams.

A pioneer seed plant. One other plant of the coal period which we shall mention is not a pteridophyte but the earliest softwood evergreen tree, a seed-bearing plant. It is called Cordaites (kor'da-ī'tēz). It grew tall and slender and its wood was resinous. The straight trunks were up to 2 and 3 feet through and they reached a height of 120 feet. The leaves were long and in some kinds they were thick and fleshy and borne only near the top of the tree. A lumberman walking through a Cordaites grove would have been delighted with the long, smooth, upright trunks.

General character of the coal forest. Suppose you could have taken a walk through one of the swamp forests of the coal age. You would have found yourself among the trunks of great Sigillarias, Lepidodendrons, Calamites, and Cordaites. Ferns would have been about everywhere — small ferns under the great trees and tall tree ferns reaching quite up to the forest roof above. Giant cockroaches 3 or 4 inches long would have been thick among the leaves. Amphibians resembling our salamanders and from a few inches up to 10 feet in length lived in the swamps. Occasionally you might have heard the croak of one of these or seen the splash as one dropped into a pool. In the coal forests, too, the early reptiles made their home. Perhaps one of them, a small forerunner of the giants of the next age, might have crossed your path.

But in all the ancient forests there were no plants with flowers. There was no hum of bees, no fluttering of butterflies, no song of birds, no running about of squirrels or other furred animals. In the warmth and stagnant moisture of the coal period the old-time plants grew with great luxuriance. The day of the flowering plants and of the higher animals had not come.



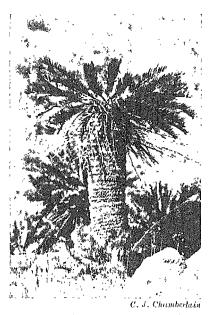
Plants of the coal period. At the left and in the background at the right are the two types of giant club mosses (*Lepidodendron* and *Sigillaria*). In the left foreground is a tree fern and at the right calamites or equisetums. In the center is a pioneer seed plant (*Cordaites*).

New forms in Mesozoic era. At the end of the Paleozoic there was a period of great upheaval. Lands rose and sank. Climates changed. In many places there are great gaps in the record of this time so that when in the Mesozoic the life story is taken up again we find greatly changed plants and animals on the scene. Most of the groups of the Paleozoic animals and plants lived on into the Mesozoic, but nearly all the species changed. The rapidly changing life conditions led to the rapid development of new species better suited to the conditions of the new time.

The Mesozoic is the era which saw the development of the first large land animals, the famous dinosaurs. In Mesozoic rocks we find also the first forms of mammals and birds. On the plant side the ferns, equisetums, and club mosses were much less prominent. The climate seems to have become drier and seed

plants had come. In the early part of the era these were all gymnosperms, but by the close of the era the first of the angiosperms had arrived.

Mesozoic gymnosperms. The Mesozoic gymnosperms were of two principal groups, the cycads and the woody tree forms. The cycads grew upright with unbranched stems and a cluster of leaves at the top like tree ferns. doubtedly they developed from the ferns. Some species of them are still found in tropical and subtropical regions. The cycads were the chief land plants of the early Mesozoic and the great vegetarian dinosaurs must have lived chiefly on them. Their leaves are leathery and tough and their abundance in



A cycad of South Africa. The cycads have short trunks and are palm-like in form. They were prominent in the Mesozoic era and still survive in the tropics and semitropics. Some of them have longer leaves than the species shown above.

The tree gymnosperms were probably descendants of the Cordaites of the coal forests. The early ones had few branches and long leaves, but later ones developed twigs and smaller leaves. These tree gymnosperms were the ancestors of our pines and cedars and firs and other evergreen trees. They were the ancestors also of the yews of Europe and Asia and of the *Podocarpus* (pŏd'o-kar'pus) of South America. Like the gymnosperms of today these early ones bore their seeds in cones; they had no flowers. They produced pollen, but it was carried by the wind and not by butterflies or bees. In the later part of the Mesozoic they were the dominant plants. Over a considerable part of the earth great gymnosperm forests are still found.

Rise of the angiosperms. Before the end of the Mesozoic the angiosperms had come and in the Cenozoic these became the chief plants. The earliest of them were trees and the prints of their leaves are abundant in the Cretaceous rocks. Among the early forms were the elm, oak, maple, sassafras, poplar, fig, and magnolia. Later the herbs appeared and also the palms and grasses. Today more than 100,000 species of angiosperms are known.

With the coming of the angiosperms the earth was provided with a vegetation truly fitted to the land. Over the moister regions forests were found. In many of the areas where there were seasons of cold and drought the herbs and especially the grasses prevailed.

With this enormously increased amount of vegetation on the land there was an opportunity for great changes and development in animal land life and the opportunity was promptly taken advantage of by the mammals and the birds. This, however, is another story and it will be told at another time.

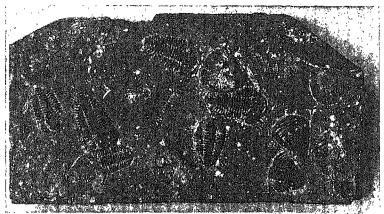
PROBLEM THREE

What Records Have We of the Animals of the Ancient Seas?

Animal life is very old on the earth. The rocks of the Proterozoic era have in them the shells of protozoa, the imprints of sponges, and the tracks of worms. Early Paleozoic fossils show that the seas of that time swarmed with crustacea, mollusks, echinoderms, and other animal forms. Some of these old-time marine animals were different from any animals that are alive today and some belonged to groups that have lived to our time.

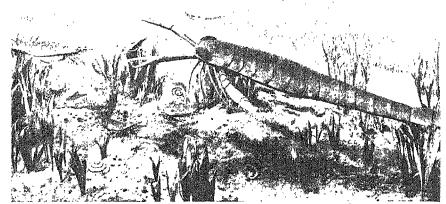
Trilobites. When the Paleozoic era opened the seas were swarming with *trilobites* (trī'lo-bīts). They had jointed legs like insects, spiders, and crabs, but they were different from any animal that is now alive. They were covered with tough skins that resisted decay and because of these skins fossils of trilobites have been preserved in great numbers. They lived through the long Paleozoic era and like our insects they were of many different kinds.

The length of the average trilobite was 1 or 1½ inches, but



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Trilobites. They were relatives of the spiders and scorpions. At one time they were abundant in ocean waters, but by the end of the Paleozoic era they were extinct.



Buffalo Muscum of Science

Eurypterids of the Devonian period. Some of them were much more scorpionlike than the ones here shown.

some were less than a fourth this length and there were a few giants that were a foot and even up to 27 inches long. Some of them were carnivorous. Some probably lived on plants. Many ate the ooze on the ocean bottom and digested the animal and vegetable matter in it. Some seem to have been bottom dwellers and others free-swimming forms. We find them in limestone, which shows that they lived in deep water. We find them in shales, which shows that they lived also in the shallower waters near the shores. In the later ages of the Paleozoic many of the trilobites had spines which doubtless helped to protect them from other animals that fed on them.

It is probable that at one time the trilobites made up more than half of the animal population of the earth, but by the end of the Paleozoic they were all dead. When we find their fossils in rocks we know that the rocks are old. Their nearest living relative today is the horseshoe crab, or king crab (page 200). The little gray sow bugs and pill bugs that we find under boards or rocks are other relatives of these old animals.

Eurypterids. Another group of animals of the old seas were the *eurypterids* (u-rĭp'ter-ĭds), or water scorpions. They had jointed legs like the trilobites and in form were much like the land

scorpions of today. Most of them were small, but a fossil of one of them has been found that was 9 feet in length. The eurypterids were most abundant in the Silurian period. By the end of the Paleozoic they, like the trilobites, had become extinct. Fossil eurypterids are of course found only in regions where Paleozoic rocks are exposed. They are abundant in some of the rock strata of Pennsylvania and New York.

Crinoids. A third group of ancient animals is the *crinoids*. Unlike the trilobites and eurypterids they are not entirely animals of the past. In the sea today we find crinoids standing on the ocean floor and spreading out their arms to catch for food the little plants and animals that die and fall down to them from above.

The crinoids belong to the starfish family and are relatives of the starfishes and sea urchins. The mouth is in the center of the body and arms reach out in all directions around the mouth. All the living crinoids have stems, as had most of the ancient ones. They live fastened in one place like plants and with their finely branched arms spread out they look so much like flowers that they have been called "sea lilies."

In some limestones we find thousands and thousands of fossil crinoids. They are the remains of the sea-lily beds of the old seas. In some places the rocks are chiefly made up of the ringed stems (about the thickness of slender lead pencils) and of the broken pieces of the arms. Some of the ancient crinoids were very similar to living forms.

Other marine animals of upper Devonian time. At the left are sponges, at the right a crinoid, toward the center a coiled and a straight-shelled cephalopod Before the fishes and sharks rose to power, the cephalopods were masters of the seas.



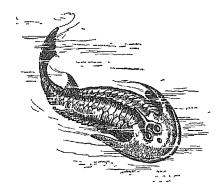
Crustacea. The crustacea (crabs, lobsters, shrimps, cray-fish, and smaller forms) are another Paleozoic group that continue to flourish in modern times. The oldest ones are found in early Cambrian rocks. The early kinds were small and the crustacea were not very important in the Paleozoic era. By the middle of the Mesozoic, however, forms much like our crabs and lobsters had arrived and in our time the crustacea have taken the place of the trilobites and eurypterids of the Paleozoic seas. Some of the kinds now living are larger than any fossil crustacea that have been found. A lobster that weighed 27 pounds has been caught and crabs that measure 11 feet from claw to claw occur in the ocean off Japan. The crustacea are an old race that show no sign of weakening with advancing years (page 825).

Mollusks. The mollusks are a phylum that has flourished in both ancient and modern times. Oysters, clams, mussels, snails, and slugs are familiar members of the group. Squids and octopuses also belong to it. Of the 45,000 different kinds of mollusks now living about 6000 are land snails. The others live in water and the majority of them have their homes in the sea.

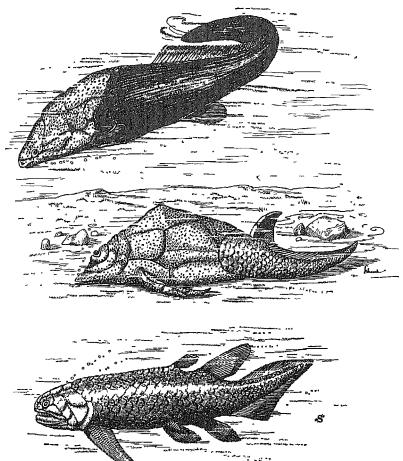
The fossils and shells of mollusks are found in rocks and in water deposits from the early Paleozoic until the present time. On the seashore today you can pick up the shells of many different kinds. On the seashores of a million, 10 million, 100 million, or 500 million years ago you could have done the same thing. The marl beds of our eastern coastal plain mark the places where hosts of mollusks died and left their shells.

The mollusks of the squid and octopus group are called *cephalopods* (sĕf'a-lo-pŏds'). Members of this group were for a long time the rulers of the Paleozoic seas. They lived in the mouths of their long shells, swam swiftly, had long, strong, grasping arms and fierce biting beaks. The octopuses and squids of today are descendants of an old-time conquering race.

Early fishes. The first fishes were small, none of them over 7 inches long. They were sluggish bottom-feeding forms. The head and fore part of the body were protected by hard scales that were joined in some forms to make bony plates. They are called



Armored Paleozoic fishes. At the left is an ostracoderm and just below an arthrodiran, one of the fishes that could nod its head. Next below is a "winged fish" that had swimming paddles. At the bottom is a ganoid whose body was covered with bony scales.



ostracoderms (ŏs'tra-ko-durms; Greek ostrakon, a hard shell, +derma, skin; shell-skinned). The figure at the top of page 163 shows one of them. These oldest of fishes died out in the Devonian period. No fishes of our day are like these ancient forms.

Another branch of the fish family that reaches far back in time is the sharks. The first of these were small (rarely over a foot long) and they had blunt, rounded teeth fitted for crushing shells rather than for cutting. They appeared in the late Silurian and sharks of this kind are yet found in Australian waters. Sharks with cutting teeth came in the late Paleozoic and became very abundant in Mesozoic time. The largest living sharks grow to a length of about 40 feet. From the size of their teeth it is estimated that some of the Mesozoic sharks were half as long again as this.

The ganoids (găn'oids) were a third group of old fishes. These had bright hard scales over their bodies. The garpike and the sturgeon of today are much like some of the old ganoids, and the lungfishes that are now found in South America, Africa, and Australia resemble others. Half the fishes of the Devonian time were ganoids and these forms were prominent until late Cretaceous times. Some of the ganoid fishes now alive are very large, but they are not abundant in numbers nor are there as many kinds as there were in earlier times.

Dinichthys, the "terrible fish." The largest of all the Devonian fishes were the armored fish, or Arthrodira (ar'throdira; Greek arthron, joint, + deire, neck; jointed-neck). The head and the fore part of the body were covered with thick bony plates, but in the neck was a joint that allowed the head to nod up and down. Forty per cent of the Devonian fishes belonged to the Arthrodira group.

One of these fish called *Dinichthys* (dī-nīk'thĭs; Greek *deinos*, terrible, + *ichthys*, fish), the fossils of which were found in Ohio, was 20 feet long and 3 feet thick. Not counting the sharks, these were the largest and fiercest fish the seas have ever known and they were masters of everything they met in the late Devonian time. The whole group died out in the next period (the Mississip-

pian). Like the feeble little ostracoderms, the great fishes with jointed necks failed to live beyond Paleozoic time.

Teleosts, or modern fish. The skeletons of all the old fishes were made of cartilage instead of bone. It was late in the Paleozoic when the modern kind with true bones appeared. They are called *teleosts* (těl'e-ŏsts; Greek *teleos*, complete, + osteon, bone). Ninety-nine per cent of all our fishes today are teleosts. They have become more and more abundant, while the old kinds have more and more died out. When we say "fish" it is of a teleost, or modern fish, that we think. Perch, salmon, cod, herring, shad, and trout are teleosts. Of the old-time fishes only a few kinds of sharks and ganoids have survived to our day.

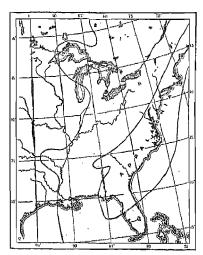
Other animals in the ancient seas were the graptolites, brachiopods (brăk'ĭ-o-pŏds), sponges and jellyfishes, sea urchins, and corals of many kinds. There were also hundreds of tiny microscopic forms, many of which were very important as limestone builders and as food for larger animals. Representatives of the groups to which they belonged are in the sea today. Some of these lower forms doubtless lived as long before the trilobites and eurypterids as these lived before our own time. Life on the earth was very old before an animal even as large as a trilobite appeared.

PROBLEM FOUR

What Were Some of the Early Land Animals?

Did you ever hear of the land called Appalachia (ăp'a-lăch'ī-a)? It was an eastern neighbor of ours that sank beneath the sea. Just how large it was or where its coast lines lay we are not sure. Doubtless it rose and fell and varied in size at different times. Geologists are sure of the existence of this old-time land because in areas from New Jersey to Alabama there are beds of sedimentary rocks thousands of feet thick, the materials of which came chiefly from the east. Appalachia now lies buried beneath the loose materials of our Atlantic coastal plain and the sea. It must at one time have been quite large and high to furnish the amounts of materials that were carried from its western slope.

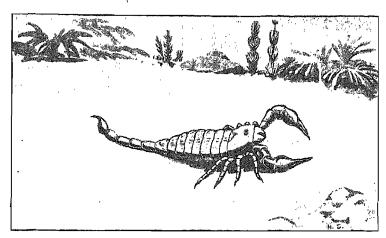
If you had visited Appalachia in early Paleozoic time what land animals would you have found? None at all. The waters teemed with life, but over the land and over all lands, save for the murmur and movement of the wind or the breaking of the waves upon the shore, all was stillness and silence. It was not until



Appalachia in the mid-Devonian period.

the middle of the Paleozoic era that animal life first left the sea and took up its abode on land.

The first land animal. What animal do you suppose first came to live on the land? It was one that you would not have cared much about. It was a scorpion. Already it had a poisonous sting and its scientific name is *Palaeophonus* (pā'le-ŏf'o-nus), which in Greek means "ancient murderer." Since it was a flesh eater and there were no other land animals for it to feed upon, it

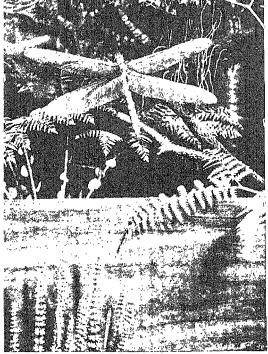


The oldest land animal, a scorpion about $2\frac{1}{2}$ inches long. This is the Columbus who, about 500 million years ago, made the passage from the water to the land. In its general body form it was much like the scorpions of today.

doubtless lived along the water's edge and pounced upon luckless trilobites and other small animals that were left on the strand.

The oldest fossil land scorpions are found in the Silurian rocks and the largest of them were about $2\frac{1}{2}$ inches long. Soon after the scorpions, thousand-legged worms appeared and by Carboniferous times the land had an abundant small animal life. Spiders and land snails lived at that time, and in the rocks of the coal strata more than 1300 kinds of insects have been found.

Early insects. The insects of this early age were on the average much larger than our insects. One shaped like a dragonfly measured 29 inches across outstretched wings. The fossil remains of more than 800 kinds of cockroaches have been collected from the lower Carboniferous rocks, and the early Carboniferous time has been called the "age of cockroaches." Some of these old cockroaches were 3 or 4 inches in length, and most of them were carnivorous. They must have lived on vegetable-eating insects and on the other small animals of their time. There were no bees or butterflies or other insects that got their living from the nectar and pollen of flowers in the Paleozoic era. At that time the flowers had not yet come.



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An insect of the Carboniferous period. It had a wingspread of 30 inches.

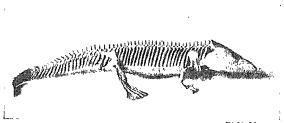
Since the Carboniferous period, insects have become smaller instead of larger. Probably the smaller kinds have been better able to escape the birds and other swift-moving animals that came to prey on insect life. No animals are so abundant in our own time as the insects, but it is the small ones that are best fitted to the world of today. The large ones have gone the way of the great cephalopods and the "terrible fish" of Paleozoic time.

First land vertebrates. The remains of

many species of amphibians have been taken from the swamps of the coal period. They resembled our salamanders rather than toads and frogs. Nearly 100 different kinds have been described, varying in length from 2 inches up to 10 feet. The larger ones had broad heads, weak legs, and heavy bodies. They were sluggish, waddling, wide-mouthed creatures that must have lived in the coal swamps much as the alligators live in our Southern swamps today.

These amphibians were the first land animals of any size. The chief food of the larger ones was probably the fishes that abounded in the fresh waters of the time. The early amphibians doubtless laid their eggs and passed the first (tadpole) stage of their lives in water. Even when fully grown they were fitted to live only where water was close at hand.

Passage to the land. Without doubt life originated in the water. Animals that live on land have water animals as



Field Museum

Skeleton of an early amphibian. These weaklegged waddling creatures lived in the Carboniferous swamps much as our alligators live in our Southern swamps today.

ancestors; so at some stage in the development of any race of land animals there had to be a passage from the water to the land. This was a great step which required the giving up of gills and the development of organs for breathing air. Aside from protozoa and worms that live in the soil, members of only three out of all the animal phyla have made the change from a water to a land life. The three phyla that have land branches are the arthropods, the mollusks, and the vertebrates.

Each of these groups developed air-breathing organs of its own kind. Of the land arthropods the insects and the millipedes (mǐl'i-pēds) and centipedes have air tubes running through their bodies; the spiders and scorpions have lung books (page 198). The land snails have a pocket-like "mantle cavity" into which they take air. The land vertebrates have lungs. The amphibians have both lungs and gills and their passage from the water to the land is not complete.

In the next problems we shall discuss the rise of the reptiles. birds, and mammals. Leaving out of account the amphibians, these are the air-breathing vertebrate groups.

PROBLEM FIVE

What Do We Know of the History of the Reptiles?

The earliest reptiles were small. They date back to the Paleozoic, but it was in the Mesozoic that they reached their full development. This was in truth the reptile age. Never has any group of animals ruled the earth as the reptiles did in Mesozoic time.

Reptiles were in the Mesozoic waters, on the Mesozoic land, and in the Mesozoic air. There were plant eaters and flesh eaters. There were reptiles twelve times as heavy as the largest elephant, and reptiles as small as mice. Some of them, although they had developed lungs, preferred a water to a land life and chased the fishes and cephalopods through the seas; others browsed on the trees and bushes as the giraffes and elephants do today; others skimmed like bats over the forests and marshes in search of insects. There were fierce carnivorous forms that devoured the planteating ones as lions, tigers, and leopards devour the herbivorous animals of our own time. The places now occupied by all the different kinds of birds and mammals taken together were once filled by reptile forms.

Water reptiles. These reptiles were air-breathing animals that went back to the sea to feast on its abundant food. The largest of the Mesozoic water reptiles were the *ichthyosaurs* (ĭk'thĭ-o-sors), the *plesiosaurs* (plē'sĭ-o-sors), and the *mosasaurs* (mō'sa-sors).

An Ichthyosaurus (Greek *ichthys*, fish, + *sauros*, lizard) is shown in the upper center of the illustration on the opposite page. The limbs of these reptiles were fins and the tail was shaped for swimming by being flattened from side to side. The ichthyosaurs were short-necked, heavy-built animals and of all sizes up to 30 feet in length. They lived entirely in the sea and the name *Ichthyosaurus*, or "fish lizard," describes them well.

The body of a Plesiosaurus was heavy and turtle-like, but the head with its sharp biting teeth was carried on a long, serpent-



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Mesozoic reptiles of water and air. The slender-necked, short-bodied one in the right foreground is a plesiosaur. To the right below is a mosasaur and to the left above it another mosasaur of a different species. The fish-like form above in the center is an ichthyosaur. In the left foreground is a turtle, an ancient reptilian form that survives today.

like neck. The plesiosaurs swam chiefly by paddles as turtles do. They were from 8 to 40 feet leng and in some of them half the length was in the neck.

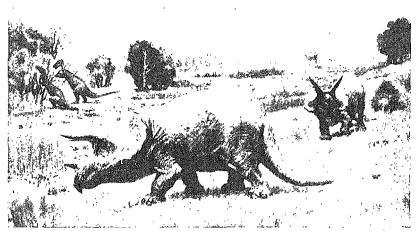
The mosasaurs were carnivorous marine lizards that developed in Cretaceous times. They reached a length of 35 feet. Some of them were whale-shaped and heavy, but in general form they were not unlike crocodiles. At one time mosasaurs lay along what is now the Philadelphia water front as crocodiles bask along the African rivers today.

Flying reptiles. The flying reptiles as a group are called pterodactyls (těr'o-dăk'tĭls; Greek pteron, wing, + daktylos, finger). There were pterodactyls with a wingspread of 25 feet that "sailed majestically over the sea; others, no bigger than a sparrow, fluttered merrily over the land in pursuit of insects; there were pterodactyls with long tails, pterodactyls with short tails, and pterodactyls with no tails at all; and while some flew by day, others, to judge from the size of their eyes, anticipated the owls and flew by night." (Lucas.)

These flying reptiles were like cold-blooded bats. The wings were made by greatly elongating one of the fingers and stretching a membrane between it and the body. The average-sized ones were 2 to 3 feet across the wings and probably weighed less than 10 pounds. The largest probably did not weigh more than 30 pounds, for the large bones were hollow and filled with air. The heads were usually long and narrow and the bodies were covered with a leathery naked skin. The pterodactyls seem to have been most abundant along ancient shores, but some of their skeletons have been found in limestone laid down 200 miles offshore. On the ground they walked easily and many of them, like our gulls and other sea birds, doubtless alighted on the beaches or soared far out to sea in search of food.

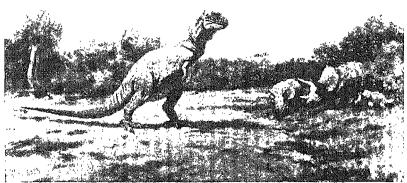
Dinosaurs. The third great group of ancient reptiles were the *dinosaurs* (Greek *deinos*, terrible, + sauros, lizard). They were the land reptiles. The "terrible fish" ruled the sea in the late Devonian and the "terrible lizard" ruled the land in Mesozoic time.

There were many kinds of dinosaurs. Some walked on four legs and some on two legs; some were herbivorous and some were carnivorous; some were heavy and slow and some were light and quick-moving. You can get an idea of their appearance by looking over the pictures of these strange beasts, or by examining



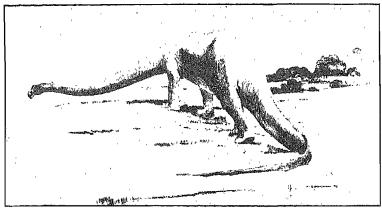
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Triceratops horridus, a vegetarian dinosaur that weighed up to 10 tons. The males fought each other fiercely, as is shown by the dents in crania and crests and by fractured jaws and horns.



American Museum of Natural History

Tyrannosaurus rex, king of the dinosaurs. This animal was 47 feet long, 18 to 20 feet high, was heavier than an elephant, and "in respect to speed, ferocity, and size was the most destructive life engine ever evolved." The jaws were 2 feet in length and were armed with rows of fierce piercing and cutting teeth.



American Museum of Natural History

Diplodocus, which was 80 feet long. This great reptile and its relatives (the brontosaurs) were the largest of land animals. They were cumbrous, slow-moving vegetarians that browsed about the Mesozoic swamps.

their fossils or the restorations of them in museums. One fact you should understand is that there were small dinosaurs as well as large ones. Just as there are mammals today ranging in size from mice to elephants, so in the Mesozoic era there were dinosaurs from the size of our small lizards up to the giant kinds that are usually described.

One distinguishing feature of all the old reptiles was the smallness of their brains. None of the dinosaurs, even though they weighed up to 40 tons, had brains that weighed more than 2 pounds. One of them, although it was bigger than an elephant, had only about $2\frac{1}{2}$ ounces of brains. Man has an average of 2 pounds of brain to 100 pounds of total weight and even with this allowance some of us are not very bright. With only an ounce of brain to a ton of body think how stupid the dinosaurs must have been!

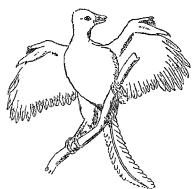
PROBLEM SIX

What Record Have We of the Origin of the Birds?

The birds are vastly different from other animals. We associate them with bright colors and flashing wings, eggs and nests, migrations and the songs of spring. Soaring above us and flitting with effortless grace from place to place, they seem superior to creatures that are earth-bound. "Free as a bird" and "happy as a lark" are expressions of our feeling that the birds typify the freedom and joy of life.

Origin of the birds. Whence came the birds? Before them the only important land vertebrates were the reptiles. Could a scaly, cold-blooded reptile have given rise to these

feathered singing creatures? It seems incredible, but biologists believe that such is the case. ternally the birds and reptiles are still much alike. Also birds continue the laying of large eggs. which the reptiles began. They have the small heads of some of the reptile groups and many of them have the serpent-like necks. Further, like the reptiles they have dry skins and on their feet scales and nails. Their feathers are developed as outgrowths of the scales of the skin. Geolog-



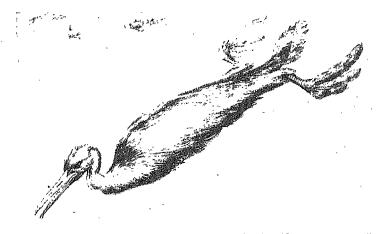
American Museum of Natural History

The oldest known bird (Archeopteryx). It had teeth and a long jointed tail with a row of feathers down each side.

ical records of the very first birds are missing, but we do have fossil remains of birds that strongly suggest relationship to the reptile group.

The oldest known bird. The earliest of the fossil remains of birds come from Germany. There, in rocks that were laid down about the middle of the Mesozoic era ("the age of reptiles"), there have been found two imprints of the oldest known

bird. It was a little smaller than a crow; it had a long body and a full set of sharp-pointed teeth in each jaw; there were claws on its wings; its tail, which had a row of feathers down each side, was long and jointed like the tail of a squirrel. This primitive bird had feathers, was fitted for life on the land and in the air, and



American Museum of Natural History

The great swimming bird (Hesperornis) of late Mesozoic time. It had teeth and was practically wingless.

was a true bird. It is called *Archeopteryx* (ar'ke-ŏp'ter-ĭks), which means "ancient wing" or "ancient flier." What birds lived before this one or for a long time after it we do not know. They seem to have been land forms and their skeletons have not been preserved.

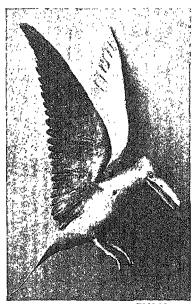
Later Mesozoic birds. In the rocks of the last part of the Mesozoic era (the late Cretaceous) fossils of much later birds are found in abundance. They were water birds, not land birds, and were very different from Archeopteryx. They still had teeth, but the long tail was gone and they were much more bird-like in form. There were two main groups of them.

One of these groups is represented by a large water bird called *Hesperornis* (hes'per-or'nis; Greek *hesperos*, western, + *ornis*, bird). It received its name Hesperornis, or "western bird," because fossils of it were first discovered in Kansas when that

state was considered to be part of the Far West. Hesperornis had almost no wings and its powerful legs were so jointed that the webbed feet stood out sidewise from the body like those of a frog. It could not fly and probably walked very poorly. It was strictly a water bird fitted to pursue fish and other animals by swimming

and diving and to catch and hold them in its long toothed beak. The largest of these great birds was 6 feet in length. Fossil specimens have been found not only in Kansas but in other Western states and also in New England and New Jersey.

The other type of Cretaceous bird is represented by *Ichthyornis*, or the "fish bird." It was a powerful flier perhaps a little larger than a pigeon — a bird somewhat like a small gull or tern. Its legs were slender and it had sharp teeth in the long jaws. It lived at the same time as Hesperornis, but far fewer of the fossils and skeletons of Ichthyornis have been found.



Field Museum

An early flier (Ichthyornis). It was about as large as a pigeon.

Later types of birds. Late in the Mesozoic the toothed birds died out and early in the next era swimming birds similar to penguins and large running birds of the ostrich type appeared. One great land bird of Wyoming stood 7 feet high. One of Argentina stood "7 to 8 feet high, with a skull 23 inches long, heavy, and decidedly beaked. Apparently it was the most terrible of birds of prey."

After these swimmers and runners came many kinds of fliers—forerunners of the parrots, flamingos, vultures, and other types that we know. Last of all and best of all came the little songbirds that add so much to the beauty of the world today. They are



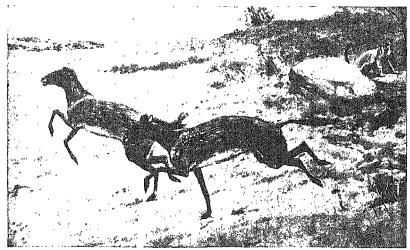
The great running bird of prey of Argentina (*Phororhacos*). It stood 7 to 8 feet high and its skull was 23

inches long.

small in size, light in body, and live on insects, seeds, and fruits. More than 7000 species belong to the songbird group and they are by far the most successful of all the bird types.

It is a great change from a reptile to a bird, but as the stream of life has come down through the ages it seems to have undergone many other changes equally marked. In nature's great book of the rocks we have pictures of a few of the plants and animals of the past and when we begin at the bottom and come up we find a con-

stant development of new and very different forms. The biologist does not believe that the birds appeared all at once—full-feathered, warm-blooded, flying through the air and singing in the trees—but rather that through millions and millions of years the members of a branch of the reptile family continued to change until now their descendants are our birds. The record of the change is incomplete, but this is not strange. The bird bones are light and quickly decay, and in consequence few of the skeletons are preserved.



American Museum of Natural History

The mesohippus, an ancestor of the modern horse. It had three toes on each foot and was about the size of a sheep.

PROBLEM SEVEN

What History Have We of the Development of the Mammals?

The mammals appeared even before the birds. The earliest fossils of them are found in the lower Mesozoic rocks. The remains indicate that the first mammals were small. They were animals about the size of rats, with the largest of them no bigger than a cat. These first mammals had many lizard-like characters. From their teeth we judge that they are all kinds of food. Everything indicates that the mammals are descended from the small reptiles of the land.

Rise of the mammals. Until near the close of the Mesozoic the reptiles ruled and the small hairy mammalian newcomers were certainly not able to dispute their power. Yet by the end of the Mesozoic the dinosaurs, the pterodactyls, and the great water reptiles had gone and mammals of many new kinds were on the scene. Perhaps the warm-blooded mammals,



American Museum of Natural History

An early carnivorous mammal (a creodont). It is one of the Archaic mammals—a member of the first old-time placental group.

active at all seasons, attacked the reptiles when they were dormant with the cold. Perhaps they destroyed the reptile eggs. Perhaps it was a change in climate and vegetation that favored the mammals so greatly, for by the end of the Mesozoic the grasses and herbs had come. However it came about, the reptiles were dethroned and the mammals came to power. The Cenozoic, or present era, is the age of mammals and the placental (pla-sĕn'tal) mammals are the dominating line.

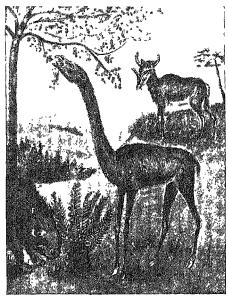
Divisions of the mammals. Turn to page 993. You will see that one group of mammals are egg layers. These are living "fossils" that lay eggs as reptiles do. The egg-laying mammals belong to an old group, the Prototheria ("first beasts"), that were the dominant mammals of the Mesozoic time.

The second group of mammals, the Eutheria ("good beasts"), is divided into two subgroups. The members of the first group, the marsupials, first appeared about the middle of the Mesozoic era. It is believed that at one time the marsupials lived over the whole earth. Now, except for the opossum and a few rat-like South American animals, they are found only in Australia and the

neighboring islands. The kangaroos, wombats, phalangers (falăn'jers), marsupial cats, and all the other native mammals of Australia except the egg layers, are marsupials.

The placental mammals are now the dominating animals They developed from the marsupials in the of the land. late Jurassic or early Cretaceous period. The first ones were small climbing forms that, if we can judge by their teeth, lived principally on insects. In a general way they resembled the living shrews (page 438). From these small forms mammals of all sizes and adapted to many different conditions of life arose.

History of the placental mammals. The fossil records of these mammals are much more complete than are the records of the reptiles and birds. We find not only their petrified remains but also their actual teeth and bones in loose materials of the Cretaceous and early Cenozoic time. The early history of



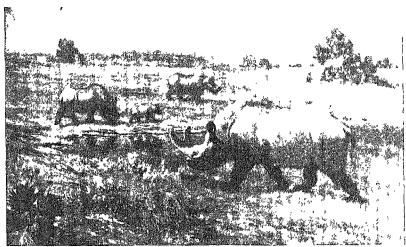
Buffalo Museum of Science

A giraffe-like camel, and in the background an early camel-antelope form. In the left foreground the head of an extinct heavybodied hoofed animal (Nesodon) is seen,



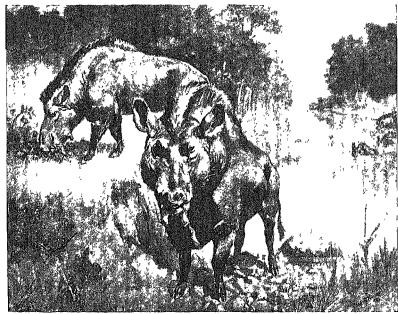
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Baluchitherium, the largest of all the la mammals. It could browse on leaves to 20 feet from the ground. It belonged the rhinoceros group.



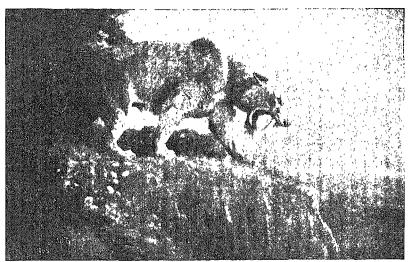
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Brontotherium, a rhinoceros-like animal of a line that is now extinct. Its weight exceeded that of an elephant.



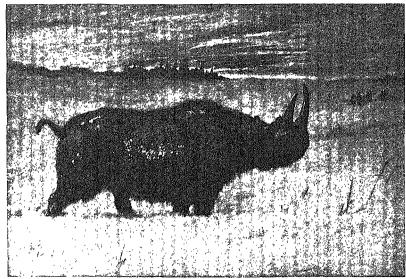
American Museum of Natural History

Giant pig-like animals (Eleutheres) that lived comparatively recently.



American Museum of Natural History

Saber-toothed tiger. This giant cat attacked and fought by slashing with its long knife-like tusks. It could not bite and hold as most cats do.



American Museum of Natural History

The woolly rhinoceros, which lived in temperate and cold regions. Note the human figures in the background. The age of some of these mammals overlaps the age of man.

these mammals has been best worked out in our own country and we shall discuss them as they existed here.

When the Cenozoic era opened none of the North American mammals were as big as sheep. Their legs were short and they had five toes on each foot. Their tails were long and heavy and their brains were very small. There were insect eaters, rodents, flesh eaters, lemurs (lē'mers), and hoofed forms. The illustration on page 180 shows one of the largest of these mammals. In your reading you may find this old-time group referred to as the *Archaic* mammals.

Then early in the Eocene there appeared in our western country mammals of a much more modern type. They came suddenly in a second great mammalian wave. Probably they were migrants from Asia, for it is believed that at times North America,



Buffalo Museum of Science

Mastodons. These animals lived so recently that the twigs in the stomachs of some that were buried in bogs have been preserved. Bodies of their relative, the mammoth, have been found in Siberia frozen in ice.

Europe, and Asia have all been one land. Among these new mammals were small horse-like forms, primitive tapirs, monkeys, pig-like and squirrel-like animals, ruminants that were the ancestors of the cattle and deer, and rhinoceroses of small size and slender limbs. These mammals gradually replaced the older kinds. They increased in size and in number of kinds and the older type became extinct. In the later Eocene there were small camels, armadillo-like animals, primitive dogs, and hoofed animals, some of which were of great size.

In the Oligocene, mammals began to take on their present-day appearances. Since that time the species and most of the genera have changed, but many of the orders that we have today existed in the Oligocene and Miocene epochs. There were rodents, pigs, camels, rhinoceroses, elephants, dogs, and hoofed animals of many kinds. During this period there were great changes in the elevation of the land and in the mammalian life it supported.

In number of species the mammals culminated in the Miocene and by the end of the next epoch (Pliocene) many of the older forms were extinct. In museums you can see restorations of many of these species. In books that describe the animals of the past you will find much about old-time mammals that will be of interest to you.

THE CONTINUITY OF LIFE AND THE CONSTANCY OF CHANGE

When the scroll of the ages is unrolled and the record of life on earth is revealed, certain facts impress us. One is that life has been continuous on our planet for hundreds of millions of years. Sometime, somewhere, in the long ago, living protoplasm came into existence. Through all the upheavals and changes of the ages it has maintained its being. The cells in the organisms of today are the direct descendants of cells that lived in early Paleozoic time. An unbroken life chain has stretched across the years. The plants and animals of today are but a continuation of the life stream of the past.

A second impressive fact is that protoplasm changes. It is not static, but dynamic. As it moves onward through the generations it displays itself in new forms. This idea is sometimes hard for us to accept, for one of the strange facts about protoplasm is that it has the ability to renew itself with great exactitude. A small amount of it—a mere microscopic speck—is enclosed with a food supply in the egg of a reptile or a bird, where in its growth it builds more and more protoplasm until there is fashioned a complete organism of the parent kind. Take an egg from this second organism, and again it grows into a complete individual like the first. No power that we know could make the egg of a duck develop into a chicken or that of a turtle into a snake. Each goes relentlessly on to the production of its own kind, and seeing this it is easy for us to fall into the belief that the different kinds of animal and plant forms remain fixed and unchanged.

Yet the Book of the Rocks offers convincing evidence that living things do change. The variation in any one generation is slight, but when change is added to change through long periods of time, forms that are very different from distant ancestors and from each other are produced. The living things of today are different from those of the past. Those of the future will be different from the ones of today. The earth changes and the living things on it also change.

UNIT COMPREHENSION TEST

- A. How have we learned of the earlier history of the earth? What are the three great classes of rocks? How was each kind formed? What are the three most important kinds of sedimentary rocks? How can sedimentary rocks be recognized? What is a stratum? What are some of the facts we may learn from rocks and the fossils in them? How do geologists determine the relative ages of rocks? How old are some rocks supposed to be? In what units do geologists measure time? What are the oldest known fossils? What evidence of life is there in still earlier rocks?
- B. Why are the fossil records of early plants so scanty? What were the early land plants like? To what phylum did the prevailing plants of the coal forests belong? What were four kinds of plants that grew in these forests? What plants were most important in the Mesozoic? When did the angiosperms appear? What were some of the early kinds?
- C. What were the trilobites like? the eurypterids? the crinoids? When did the crustaceans become prominent? Tell about the Paleozoic mollusks. What were the earliest fishes like? Describe some of the other old-time fishes. How do the modern fishes differ from the ancient fishes?
- D. Describe the first land animal. What were some other early land animals? Describe some of the insects of the Paleozoic era. What kind of animals were the first land vertebrates?
- E. In what age did the reptiles rule the earth? Describe three kinds of Mesozoic water reptiles. What were the flying reptiles called? the land reptiles? What were they like?
- F. How is it believed that birds originated? In what ways do birds resemble reptiles? What was the earliest known bird like? What were some of the other ancient birds? Which groups of birds developed last and how do they differ from the more ancient birds?
- G. When did the mammals first appear? What are the principal divisions of the mammals? To which division do the important mammals of today belong? What kind of animals were the earliest placental mammals? Name some large mammals that are now extinct. Does the history of life on the earth justify the conclusion that living things may change?

SUGGESTED ACTIVITIES AND APPLICATIONS

- 1. Find the geologic age to which rocks exposed in your region belong.
 - 2. Class projects:
 - a. Bring in different kinds of rocks. Classify them as igneous, metamorphic, or sedimentary and lay them out in three groups. Then identify each of the individual rocks as nearly as is possible. Limestone may be recognized by the fact that when it is touched with a drop of acid gas bubbles off.
 - b. If there are fossils in the rocks of the region, let the members of the class bring in as many specimens as they can find. Let them bring to school also any other fossils they possess. Arrange the fossils by phyla and learn as nearly as possible the geologic age of each fossil.
 - c. Members of the class skilled in modeling may prepare a parade of the land vertebrates. Such a parade may be prepared also by clipping silhouette animals from cardboard. These may be supported in the manner of paper dolls or fastened to the wall by Scotch tape.
- 3. Visit a museum if possible and study fossils and restorations of extinct animal forms.
- 4. There were more species of mammals in the Tertiary than there are now. Explain this decrease in the number of species.
- 5. Account for the fact that the larger species of insects have become extinct.

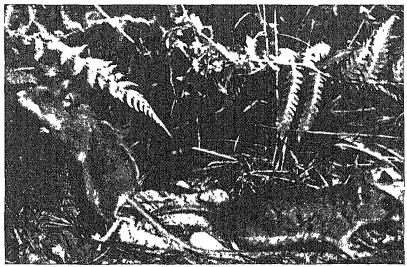
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unit 5

FUNDAMENTAL LIFE PROBLEMS

The primary problems of life are common to all living things. Different types of organisms meet these problems in different ways.



Fish and Waldlife Service

"The man, the plant, the beast, must all obey this law,

Since in the early dawn of this old world The law was given."

T. D. A. COCKERELL

THE COMMON PROBLEMS OF LIVING THINGS

QUESTIONS FOR CLASS DISCUSSION

Counting number of individuals as success, what land animal would you say is most successful? How would you explain the success of this organism?

AN organism, be it great or small, must secure food if its life is to go on. It must have oxygen. It must have a way of getting rid of its cell wastes. It must escape its enemies and be able either to endure the physical hardships of its environment, as drought or cold, or to protect itself from them. It must, if its species is to continue, produce offspring that will carry on the race. All living things have in common the problems that grow out of the necessity for food, oxygen, protection, and the perpetuation of the race.

These problems are solved by different types of organisms in different ways. There is a plant way and an animal way of living. There are infinite variations of each of these ways. The water plant absorbs its minerals directly from the water and the land plant must get them from the soil. The wolf gets its food by hunting and the clam by straining water through its gills. Different kinds of organisms are very different, but all of them by their structure and ways of living are adapted to satisfy the same fundamental needs. In a general way the basic life problems of an organism can be divided into those that relate to the survival of the individual and those connected with the continuance of the race. This unit will be devoted to the problems of individual survival and in the next unit reproduction will be taken up.

The chief purpose of this unit is to help you understand and appreciate the living world about you. In this world there is meaning in structure and function; all is fitted for efficiency and use. In every plant and animal there are adaptations for satisfying the requirements laid upon the organism that are marvelous to contemplate. Each organism is fitted to live in its own way and its organs and parts are modified and adapted in accordance with the problems that it meets. The study of the unit should extend your conception of the unity of life and deepen your understanding of how the diversity in living things adapts different organisms to different conditions and different ways of life.

Problems in Unit 5

- 1 What is the fundamental difference between the plant and the animal way of getting food?
- 2 What different arrangements have living things for taking in oxygen and giving off carbon dioxide?
- 3 How do living things protect themselves against other living things?
- 4 How do living things protect themselves against the dangers of their physical environment?
- 5 What are some unusual methods employed in meeting life problems?

PROBLEM ONE

What Is the Fundamental Difference between the Plant and the Animal Way of Getting Food?

"Building is the peculiar work of plants; for only plants have the power of changing air, water, and earth into organic material." ASA GRAY

Plants and animals obtain food in very different ways. Green plants make their own food.¹ They take in carbon dioxide, water, and minerals and out of these materials they build the food that they require. Animals lack food-building power; they live on foods that plants have already prepared. Every animal feeds either on plants or on other animals whose food comes from plants.

Primary food-building process. In the green tissues of a plant there is found a green pigment called chlorophyll. This is a chemical compound of extraordinary qualities. In the



Where the leaf is covered from the light no starch is produced.

presence of light it causes carbon dioxide and water to combine. The combining process is called *photosynthesis* (Greek *photos*, light, + *synthesis*, putting together) and it results in the formation of sugar.

A leaf on a tree takes in carbon dioxide from the air, and water comes up to it from the soil. Under the influence of sunlight the leaf's chlorophyll causes the carbon dioxide and water to unite and sugar (glucose) is formed. In photosynthesis oxygen is set free. The chemical equation for the process is:

$$6 \text{ H}_2\text{O} + 6 \text{ CO}_2 \longrightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2$$
 $6 \text{ molecules} + 6 \text{ molecules of } \text{yield} \quad 1 \text{ molecule of} + 6 \text{ molecules of } \text{oxygen}$

¹ The discussion of plant nutrition here given applies only to green plants. The fungi lack chlorophyll and in consequence are unable to carry out the primary step in food synthesis. Their nutritive processes and methods are considered in a later unit (page 293).

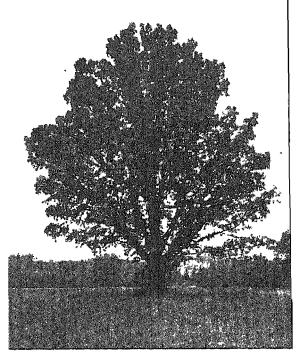
Energy is required to bring about this chemical change. The energy used comes from the sunlight and is stored in the sugar molecules that are formed. Burn the sugar and the stored energy will be transformed into heat and light.

Other foods built by plants. Surplus sugar in a plant is changed into starch and stored. Also by chemical changes oils are made from sugar, and by rebuilding the molecules and adding to them nitrogen, sulfur, and other substances, proteins (prō'te-ĭns) are built in the plant cells. In a grain of corn you will find a store of starch, protein, and oil — all built by the corn plant.

The corn plant takes carbon dioxide from the air and water and minerals from the soil. Out of these simple materials it makes the foods that are in the corn grains. Energy is stored in the molecules of these foods. This is the energy of the sunlight that was caught in photosynthesis, the first and fundamental step in the chemical building processes that green plants carry on.

The animal way of securing food. Animals in comparison with plants are lacking in building power. They have no chlorophyll and in consequence no power of photosynthesis. They cannot build proteins. They cannot manufacture even many of the vitamins that they must have to live. The whole animal world subsists on foods that are built by green plants, and different animals have different methods of securing an adequate supply of these foods.

Some animals feed on the leaves and tender shoots of plants. Some live on fruits and seeds. Many, like the earthworm and the ooze eaters of the sea, subsist on dead organic materials. The oyster and clam strain water through their gills and find their nourishment in microscopic organisms they collect. The wolf and the spider represent the carnivores (kar'nĭ-vōrs) that get their food second or third hand from plants by feeding on other animals. Yet though different animals eat different foods and obtain their food by strikingly different methods, in the end all animals are dependent on plants for their subsistence. The green plants are the food makers of the world and animal life is supported by them.



The plant stands in one place and by spreading out its leaves to the sunlight builds its own food. This is the plant way of life and the plant body is built to live in accordance with it.

Adaptations to methods of food aetting. When we consider and compare the form and the structure of a tree or other land plant with that of one of the higher animals, we note many adaptations of each type of organism to its way of securing food. The plant has roots that draw water and minerals from the earth, leaves that manufacture food, and a stem that holds the leaves up to the light. The walls of its cells are of stiff cellulose and there are hard sup-

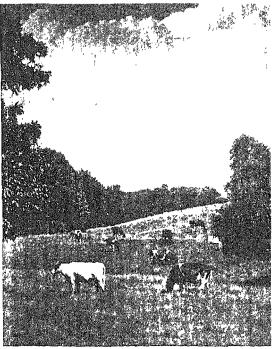
porting tissues that strengthen and make rigid the plant body as it battles against the wind. The plant has no muscles, no nervous system, no organs for catching or digesting food. It has no organs corresponding to kidneys to excrete its protein wastes, for when its tissues break down it builds the fragments up into proteins again. The plant stands in one place and makes its own food. This is the plant way of life and the plant body is built to live in accordance with it.

In contrast the animal is fitted to move about in search of food that is already prepared.¹ Its cell walls are of flexible albumen, which allows its body to bend easily. It has muscles that move it,

In the present discussion only the typical land plant and the typical animal are considered. What is said does not apply in full to parasitic animals or to stationary water forms that get their food by setting up currents that bring a food supply to them.

a nervous system that

controls the muscles. eves and other sense organs that serve as guides, and organs for taking in and digesting food. It is a spendthrift in regard to food and when the foods break down within its cells it has organs (lungs and kidneys) for casting out the fragments as wastes. An animal is fitted to live by feeding either on plants or on other animals. This is the animal way of life and the animal body is built to live in accordance with it. The plant cannot live in the animal way and the animal cannot live in the plant way. own plan.



Cornelia Clarke

The animal, in contrast to the plant, subsists on food that has been already prepared. It has organs that enable it to find and use this food. Like the plant, the animal is adapted for life according to its own plan.

y. Each is fitted for life according to its

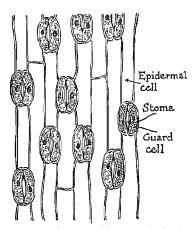
Plants and animals are the two great groups of living things. The plant line begins in one-celled forms and following its own way upward it leads to the trees and flowers. The animal line likewise begins in one-celled organisms and develops in its way until it culminates in the fishes, birds, and mammals. It is most interesting to observe how plants in their way and animals in theirs have solved the problem of a food supply under different conditions until both plants and animals are able to exist practically everywhere on the earth.

PROBLEM TWO

What Different Arrangements Have Living Things for Taking in Oxygen and Giving off Carbon Dioxide?

Oxygen is free in the atmosphere and dissolved in the waters of the earth. There is no need for living organisms to make it or to take it from others. What is needed is a way of getting a supply of it out of the air or water. Small organisms simply absorb the oxygen that they need, but larger ones have special structures and organs to help them secure an adequate oxygen supply. It is the adaptations that larger organisms have for getting oxygen that we shall study in this problem.

How plants obtain oxygen. A plant leaf has a covering that is called the *epidermis*. In most leaves this is only one layer

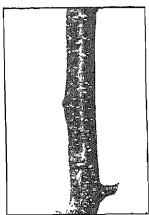


Stomata in the epidermis of a leaf. Through these little openings the cells in the interior of the leaf get oxygen from the air.

of cells thick. By carefully tearing a leaf or by the use of a pin or a needle you can probably separate a piece of the epidermis from the other leaf cells. The epidermis is transparent like a piece of thin waxed paper and it protects the leaf from drying out.

The epidermis would shut off the inner cells of the leaf from the oxygen of the air also if it were not filled with very minute openings. These are called *stomata* (stō'ma-ta; singular stoma). They allow an exchange of oxy-

gen and also of carbon dioxide between the cells of the leaf and the air. Examine a piece of epidermis from the lower side of a leaf under a microscope and you will see the minute openings in it. An apple leaf has about 24,000 stomata to a square inch of surface area.

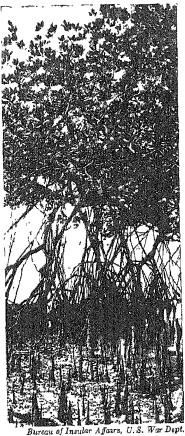


Hugh Spencer

Lenticels. They are porous places in the bark that put the cells within the twig in communication with the air.

View in a mangrove swamp. The mangrove is a shrub that grows in tidal swamps in tropical regions. The upgrowths seen in the foreground help the buried roots to secure oxygen.

The living cells of the twigs must also have oxygen and they get this through lenticels (len'ti-



sels). Examine a twig and you will see the lenticels as little spots over it. They are places where the cork of the bark has become They allow oxygen to pass into the cells within the twig and carbon dioxide to pass out from them. In the bark of a cherry or a birch tree you can see where, as the tree and its branches have grown in diameter, the lenticels have been stretched out into horizontal lines.

The roots of plants, too, must have oxygen. Ordinarily roots absorb oxygen from the soil, but many swamp plants have special arrangements for getting it. Cattails and rushes have hollow stems through which air can reach the roots. The roots of many swamp trees have upward growths that rise above the mud.



The lung book of a spider. The blood as it circulates through the thin leaves of the book absorbs oxygen from the air.

There is little oxygen in swamp mud and by this arrangement the roots of swamp trees are able to take oxygen from the air. The "knees" in a cypress swamp are growths that put the roots in communication with the air.

How water animals secure oxygen. Water animals in general secure oxygen by means of gills or other organs through which oxygen can be absorbed from the water into the blood. The general plan of a fish's gill is shown in the illustration. Blood flows through the gill and as it does so oxygen is absorbed into the blood from the water. The gill has many fine little filaments that float in the water and expose a great amount of surface to it. Watch a fish as it lies quiet in the water and you will see it move its mouth as if swallowing. This motion is comparable to our breathing. By it the fish takes water into its mouth and sends it out over the gills.

The larger crustacea (e.g., crayfish, crab) also have feathery plumed gills; and the mollusks like the oysters and clams have gills that are leaf-like sheets with many openings in them through which the water passes. Sea slugs have fine-tufted gills over their bodies and many sea worms have a fringe of feathery gills about the mouth. As we study different types of water animals we shall learn in more detail of their oxygen-absorbing organs and methods.

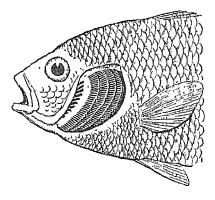
How land animals secure oxygen. Gills will not work in the air. Out of water the fine moist filaments stick together and the oxygen of the atmosphere cannot then reach

them. Land animals have special air-breathing organs and these organs are of two main types — breathing tubes and lungs.

Insects and their allies have openings on the sides of their bodies and branching air tubes, or *tracheae* (trā/ke-ē), that carry oxygen into the tissues. The land vertebrates have lungs made up of many little air sacs with blood vessels in their walls. The air is drawn into the lungs and the oxygen is absorbed into the blood through the thin air-sac walls.

in little pockets that open to the air. One of these is made up of a collection of thin plates that lie side by side as do the leaves of a book. The "leaves" are dry and do not stick together as moist gills do. They are very thin and as the blood flows through them oxygen is absorbed into it from the outside air. trilobites had "gill books" and spiders and scorpions are relatives of these animals of the The gill books ancient seas.

The spiders and scorpions have a third way of securing oxygen, that is all their own. They have "lung books" placed

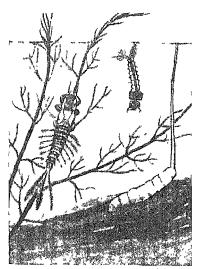


Gills of a fish. As the water from the fish's mouth passes out over the fine gill filaments, oxygen is taken into the blood.

were transformed into lung books when the ancestors of the spiders and scorpions left the water for the land.

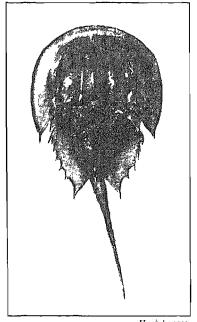
How water-living insect larvae get oxygen. Insects are air breathers. Yet a surprising number of them pass the first (or larval) stages of their lives in water. In ponds or streams insect larvae are common. How do they get oxygen down in the water away from the air?

Some of them have breathing tubes that they thrust through the surface of the water to the air. Others have thin tufted or plate-like gills that absorb oxygen from the water and pass it on into the air tubes of the insect's body. These "tracheal gills" are



Hugh Spencer

Larvae of water insects. The May fly larva (left) absorbs oxygen through the delicate, fringy gills that are seen on its body. The mosquito wriggler (center) takes air into its tracheal system through a tube at the back end of the body. The rat-tailed maggot (larva of the drone fly) has a long tube that it thrusts upward to the air.



Hugh Spencer

The horseshoe or king crab. It is a relative of the trilobites and the only living animal with gill books. It reaches a length of 18 inches. Its gill books are so large that they are easily seen.

found only in the larvae of insects, being a special adaptation for a water life. They disappear when the insect takes its adult form.

In this discussion we have said little about carbon dioxide, but you will understand that, in both gills and air-breathing organs, as oxygen is taken in carbon dioxide is given off. Oxygen is required to keep the life fires burning within the cells. The carbon dioxide is a waste product of the respiratory process and the cells must get rid of it. The same organs that are used to take in oxygen are employed for giving off the carbon dioxide waste.

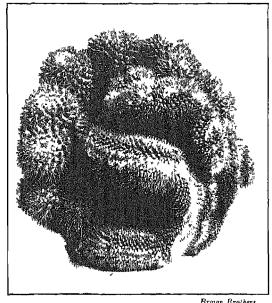
PROBLEM THREE

How Do Living Things Protect Themselves against Other Living Things?

The world is a place of fangs and claws and stings and hungry mouths. "To eat and not be eaten is the goal of animal life." One of the great problems of living things is to protect themselves from other living things and we find many devices for doing this.

Protective adaptations of plants. Thousands of plants have tastes and smells that are offensive to animals. Some are poisonous. Many are spiny. Trees build woody trunks that

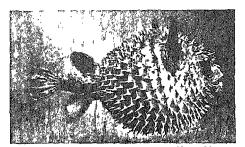
lift their tender parts and fruits above the reach of grazing and browsing animals. Against the attacks of smaller as well as larger animals plants have protective devices. There is something in the leaves of many trees that makes them unattractive to the Japanese beetle. Chinch bugs. which sap the life of wheat and corn, do not attack soy beans. Sorghums are being bred that the grasshoppers of our Western plains will not eat. Hairystemmed strains of alfalfa that plant lice do not attack are being selected.



Brown Brothers

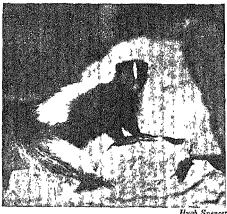
This cactus has a defense mechanism that allows it to grow in safety among the hungry herbivorous animals of the desert.

Plants must support the whole animal world. They are the natural food of animals and must be constantly eaten by animals. Yet everywhere the plants survive. The ones like the grasses, that offer no defense against



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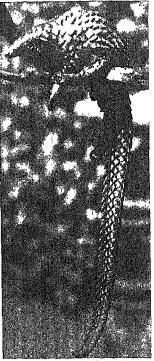
The porcupine fish is protected in the same manner as the cactus.



The skunk has a method of defense all its own.



William and Irene Finley
The spotted coloring of the rock ptarmigan
helps to conceal it.



Nature Magazine
The African pangolin relies for
safety on a coat of heavy scales.



New York Aquarium Photo

The leaf fish of tropical American fresh waters looks like a dead leaf.



A O Gross courtery Nature Magazine

The armadillo relies on an armored defense.



Allen Frost

The tortoise follows the same plan as the armadillo.



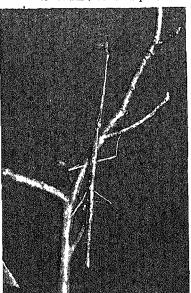
Lames Sandons

The spines of the thistle equip it for survival in a pasture.



U S Dept Agriculture Bur of Entomology and Plant Quarantine

This insect is inconspicuous because of its resemblance to a green leaf.



Hugh Spencer

And this one escapes the birds because it has the appearance of a twig.

the animals, have the power when bitten off to spring up from the roots again and again. This power of regeneration—of growing a new body from a part of an old one—is one of the main factors in enabling plants to maintain themselves as they do.

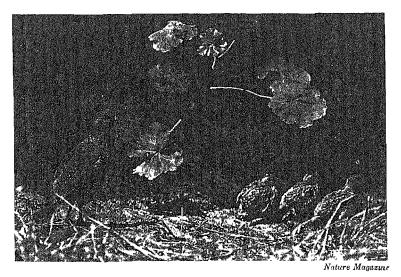
Common protective devices in animals. A common protective device in animals is a shell. Group after group has developed this as a method of protection against its foes. Tiny protozoa leave their shells in such numbers that they form chalk deposits in the sea. Many marine worms secrete a limy tube in which they live. The brachiopods that were so abundant in the old seas were shelled animals. The mollusks are a shelled group. Crabs and other crustacea have hard coverings which we call shells, as have the turtles among the reptiles and the armadillo among mammals. This list is enough to show that a hard body covering that is difficult for a foe to pierce or crush is a very common protective device.

Another protective method very common among animals as well as plants is the development of *spines*. The sea urchin is a mass of spines. There are spiny crabs, spiny fish, and spiny lizards that are difficult to swallow. Among mammals the spiny anteater of Australia, the European hedgehog, and the porcupine have developed spines. Many shells, too, are spiny and the occupants of these have the advantage of both a protective covering and of spines or spikes that make it difficult to attack the covering. The stiff bristles of many caterpillars serve the same purpose as the spines of larger forms.

A third method of protection in animals is the development of offensive tastes and smells. The skunk is so well protected that it is unmolested by other animals. The common toad has a secretion from its skin that is distasteful to a dog. Many kinds of butterflies have bitter tastes that cause birds to leave them alone. Animals may escape not only the lower animals but man also because they do not make pleasant-tasting food. Crows are allowed to multiply, while we hunt out and destroy quail, woodcock, and other game birds.

Protective coloration. Many animals, perhaps most animals, are protected by a resemblance to their surroundings. They have protective coloration. A quail and a rabbit are very difficult to see in dry grass. The white animals of the Arctic are inconspicuous as they move across the snow. The resemblance of a toad's coloring to that of the earth helps conceal it. A katydid is hard to see among green leaves. The pale under-color of birds makes them less easily visible against the sky, while their dark upper-color makes them less conspicuous when seen from above against the earth. The light and dark colors on the lower and upper surfaces of fishes protect them in the same way. In a mass of floating seaweed are found green shrimps and many other small animals colored in a way that makes them difficult to distinguish.

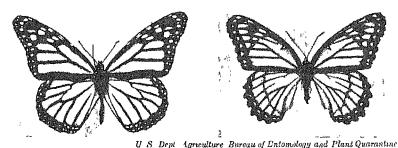
An interesting fact in connection with this protective coloring is that some animals can change their colors to conform to their surroundings in different environments. Squids, many fishes, and some lizards and frogs have this power. Buried in the skins of these animals are motile cells with pigments in them of different



A family that can quickly disappear from sight. They have a protective coloring and the instinct to remain motionless as they hide in the leaves and grass.

colors. The pigment may be red, orange, yellow, or black, and each of the cells can spread out into a thin layer or draw up into a little ball. If the animal is on a green object or among green objects the green cells expand and the others contract. Among the red corals of the tropic seas it is the red cells of the squids and fishes that spread out. If both the black and the yellow expand a brown effect is produced, and other combination colors are possible. Because of this ability to change color the animals can move from place to place and have the advantage of protective coloration wherever they go.

A special kind of protective coloration is found in animals so spotted and colored that the body outline is broken up. This prevents the animal from being seen as a silhouette against the background of its environment. Protective coloration of this kind is called *disruptive coloration*. The rock ptarmigan and the skunk (page 202) and the panda (page 443) furnish examples of it.



The butterfly on the left (Monarch) has a bitter taste. The species on the right in its coloring mimics the inedible Monarch and so escapes being eaten.

Mimicry. Among insects we find many cases of animals resembling other objects or other animals and thus escaping their foes. On page 203 is a photograph of one insect that looks like a dead twig and of another that has the appearance of a green leaf. Above is a butterfly that has a bitter taste and so escapes the birds, and another species which closely resembles the distasteful one. This imitating of objects or of other species is

called *mimicry*. It may be in form or color or in both, and it results either in actual concealment of the organism or in its being mistaken for something else. Insects furnish the most striking examples of it.

The protective arrangements we have discussed in this problem are purely defensive ones. They are passive devices which nature through variation and selection has worked out for the defense of various organisms, and not weapons and methods which are actively used. We might extend the problem to include a treatment of beaks, fangs, claws, and stings, but these are often employed offensively as well as defensively. We might include also as methods of protection the digging of burrows and the building of houses, but a discussion of these would go beyond our purpose. We have attempted only to call attention to a few of the more common adaptations that without effort on the part of the plants and animals possessing them help them to evade the attacks of other living things. The possession of these adaptations by so many organisms shows the importance of the subject we have discussed.



Cornelia Clarke

Two methods of meeting the winter's cold. The deciduous trees drop their leaves and in spring grow new ones. The evergreens have small, tough leaves that endure the cold.

PROBLEM FOUR

How Do Living Things Protect Themselves against the Dangers of Their Physical Environment?

Where currents flow near coasts, seaweeds and shore animals are in constant danger of being carried to the open sea. On small islands flying insects are in constant danger of being blown away from the land. Hail may cut plants to pieces and kill birds, and winds make difficult the lives of many organisms. Taking the earth as a whole, however, the two greatest dangers of the physical environment over much of the earth are cold and lack of water. Over a great part of the land area winter brings a covering of ice and snow and in much of the torrid zone there are alternate wet

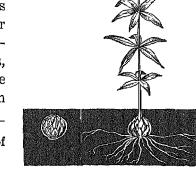
and dry seasons. Our present study will be limited to a consideration of how plants and animals survive the periods of cold and drought they must meet.

Plants in winter. Many plants live through the winter in their seeds. They are annuals (Latin annus, year), which means that they live but a single year. They are killed each autumn by the cold, but before they die they produce seeds with an embryo plant in each. The little plant within the seed is resistant to cold. It lies dormant in the seed through the winter and when the warmth of spring comes it grows. Without seeds great numbers of our plant species would be wiped out by a single night of severe cold.

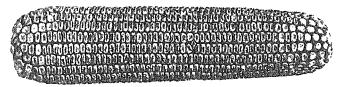
Other plants pass the winter underground. The top dies when cold comes, but the roots or underground stems remain alive. Then in spring new shoots spring up from these underground parts. Asparagus, rhubarb, peonies, tulips, lilies, and columbine are plants of this kind. You can name many others for yourself. The top parts of such plants cannot endure exposure to the winter air, but the parts of them that are protected by the earth survive.

The trees and shrubs whose tops as well as roots survive through the winter are divided into two classes, the *deciduous* and the *evergreen*. The deciduous ones ripen their tender twigs (i.e., the twigs become woody) and drop their leaves. Their woody

trunks and twigs endure the cold. Then when spring comes new leaves are grown. The evergreens have tough leaves and these as well as the stems live through the winter. In our Northern states few plants except the pines, firs, spruces, junipers, and related trees are evergreen. In the South, in



The lily way of passing periods of drought and cold.



The corn plan, which is the one employed by all annual plants.

addition to this type of tree, broad-leafed evergreens like the magnolia, honeysuckle, myrtle, mistletoe and live oak are found.

Note the condition of the plants about you in winter and the preparations that they make for winter. All but the evergreens very definitely get ready for it. They go into a dormant condition where they have little need of water and use but little food.

Animals in winter. What animals would you see during a walk on a cold winter day? Only a few birds and perhaps a mouse, a rabbit, or a squirrel. By the time winter comes most of the birds have gone South. They meet the problem of cold and a vanished or greatly diminished food supply by migrating to a warmer clime. The snakes, lizards, and tortoises are all asleep. The toads have burrowed into the earth. The frogs have gone down into the mud. The groundhogs are in their winter sleep deep in their burrows. The insects are dead or hidden away in crevices where only a few of them will survive.

Some of the insects pass the winter only in the eggs and some pass it as grubs in the earth. All the cold-blooded vertebrates and some of the mammals go into a dormant condition. Like the plants that survive as seeds or without top parts or leaves, these animals do not try to carry on active life during the period of cold. In the dormant condition the production of energy in an animal is very low and little food is required. The animals during their hibernation (Latin hibernare, to pass the winter) subsist on food stored in their bodies before the sleep begins. The bear goes into winter quarters fat and comes out thin.

Most of the animals that remain active during the winter (e.g., mice, rabbits, squirrels, raccoons, and weasels) make for themselves warm nests in which they spend much time sleeping when

the weather is unusually severe. Many of them lay up supplies of winter food. Some, like the rabbit, are able to endure the cold and continue their active life practically at all times. Such hardy animals follow the same plan of constant activity as the evergreen plants that retain their leaves and carry on photosynthesis throughout the year.

How plants survive dry seasons. When the hot dry season of the tropics comes on, plants respond much as they do to winter cold. Where trees grow, some of them drop their leaves. Many of the plants, in-



Cornelia Clarke

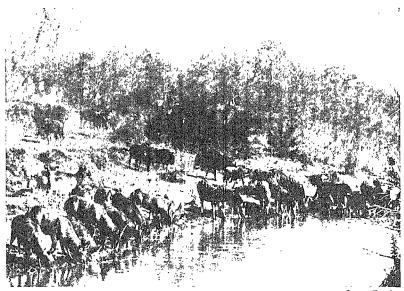
The pocket gopher. It is one of the animals that passes the winter asleep in its burrow.

cluding the grasses, are annuals that pass the drought period in the seed. Sometimes the zones of wet and dry seasons on the margins of the tropical rain belt are called "the grasslands" because they are covered with grasses. The Sudan in Africa, where great bands of antelope and zebra are found, and the llanos and pampas of South America are in the belts of alternate droughts and rains.

In temperate regions where there is seasonal rainfall or where there may be periods of drought during the growing season plants adjust themselves to the conditions that they meet. Small annuals may do their growing during the season of rains. In seasons of drought many of the larger plants drop a part of their leaves. One tree that grows over nearly all the United States is the cottonwood. Watch it in time of drought and you will see that it not only drops many of its leaves but also cuts off twigs and small limbs.

Animals in dry seasons. In the dry season the poors and small streams dry up. Then many of the larger animals migrate to regions where water can be found and food is more

LIFE PROBLEMS



James Sawders

More than is generally realized, the larger herbivorous animals (also the carnivorous ones that prey on them) migrate with the seasons. Many of those that live in high mountains come down in winter, and in the wet and dry belts of the tropics they follow the rains. The photograph shows animals at an African water hole.

abundant. Many of the small animals of the swamps and pools, including fishes, go down into the mud. Snakes and other land animals seek out as cool places as they can find and go to sleep. This summer sleep is called *estivation* (Latin *aestas*, summer) and is quite comparable to the hibernation of animals in colder lands.

An interesting example of the estivation of an animal is furnished by the African lungfish, one of the fishes that have not only gills but also a simple lung. It lives in pools that are flooded during the rainy season, growing fat on crustacea, mollusks, and other small animals. Then when the dry season comes and the pools dry up it retreats down into the mud, secretes a kind of slime, and out of this and mud makes a "cocoon" about itself with a hole through which it can breathe. In this manner it passes the dry months and when the rains come it again resumes

its active life. It has been carried alive from Africa to Europe in its mud nest. It is a large and heavy fish that grows to a length of 6 feet. The native Africans dig it out of the beds of dried-up pools for food.

An organism must live in hard times as well as good times. Its life is continuous and the life of its offspring is but a continuation of its own. In this problem we have merely tried to direct your attention to some generally employed methods of making the necessary adjustment to periods of cold and drought. It would be very interesting to take up the study of the distribution of life on the earth and to note how the adaptations of the organisms that live in different environments (desert, mountain, arctic, tropic) protect them against the physical dangers they must meet. We are, however, considering here only a few general protective methods. In books on plant and animal ecology you will find the subject of the environmental relations of living organisms treated in detail.

PROBLEM FIVE

What Are Some Unusual Methods Employed in Meeting Life Problems?

Whenever we see a living thing we know that it has some way of satisfying its fundamental life requirements. The fact that it is alive proves that it gets food and oxygen and that it finds protection from foes and the dangers of its environment. In our studies thus far we have discussed usual ways of meeting the great problems of physical survival. We shall now consider some unusual methods.

How termites secure food. You have heard of the termites that are so destructive to houses. They live in large colonies and feed chiefly on wood. This, like starch, can be broken down into sugar; but to convert the wood to sugar an animal must be able to digest it. This the termites cannot do. Wood is useless to us as food and it would be useless to the termites too if they did not have the aid of small friends.

Termites have in their intestines a certain kind of protozoön. These protozoa have enzymes that digest wood and when the termites chew up and swallow the wood the protozoa take the wood particles into their bodies and digest them. Then both the protozoa and the termites are able to use the wood as food.

To increase further their food supply, termites cultivate mold gardens. They prepare beds of vegetable and animal materials and in them plant mold spores. As the mold grows the young termites and the king and queen are fed on the filaments. When a young termite king and queen go out to found a new colony the queen carries with her a supply of mold spores.

Plants that prey on animals. It is common for animals to use plants for food. A very few plants turn the tables on the animals and use them for food. The plants that do this are small and the animals they catch are small ones, such as ants and flies. Most carnivorous plants grow where it is difficult for them to obtain the food materials they require.

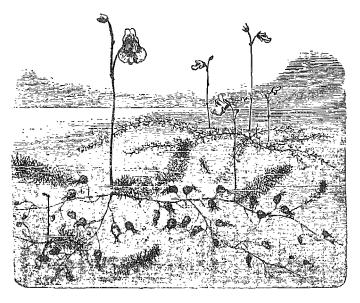
Pitcher plants. In the bogs of our Eastern states several kinds of pitcher plants grow. The leaves of these form vessels that hold water. Ants, flies, and other small insects fall into the water within the leaf and drown. They are then digested and absorbed as food. The pitcher plants have difficulty in getting the substances they need for their protein building because where they grow the vegetation of the bogs does not decay. The trapped and digested animals supply this protein need. All carnivorous plants secrete enzymes that digest their food for them.



Nature Magazine

A Southern pitcher plant (spotted trumpet leaf). It uses for food insects and other small animals that fall into the water in its hollow leaves.

Bladderwort. In fresh-water pools there grows a small plant called *Utricularia* (u-trīk'u-lā'rĭ-a), or bladderwort. It has little sacs, each with a trap door that will allow small crustacea and other animals to enter the sac but will not permit them to come out again. Near the door are hairs or bristles and when these are



The bladderwort. The small hollow bags are traps in which the plant-catches small animals for food.

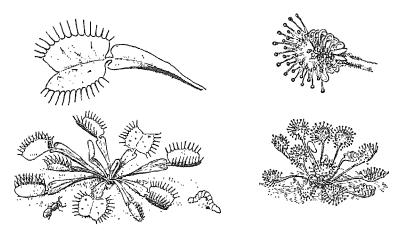
touched the sac expands and draws in water, sucking in with the water any tiny animals that may be near the door. After the animals are trapped they are digested by enzymes that are secreted into the water in the sacs. Then they are absorbed by the plant and used as food.

The sundews. In the sandy soils of our Southern states there grow little plants called sundews. They grow as rosettes close to the ground and are only a few inches across. Their leaves end in little disks that have hairs sticking up over them and on the ends of the hairs is a glistening sticky liquid.

Ants, flies, and other small animals become entangled in the liquid on the hairs, and when this happens all the hairs about the

animal bend over and help to cover the captive and hold it down. Enzymes are secreted and the animal is digested and absorbed. When this has been done the hairs straighten up again.

Venus's-flytrap. A rare plant found only in certain localities in North Carolina is called Venus's-flytrap. The ends of the leaves are expanded into little traps that will spring shut when the hairs on them are touched. After an insect or small worm is trapped,



Venus's-flytrap (left) and sundew. They grow in sandy soils and increase their food supply by trapping and digesting small animals.

it is digested and the products of the digestion are absorbed into the leaf.

Both the sundew and the Venus's-flytrap grow in sandy soil where vegetable matter and minerals are scarce. By trapping animals they gain an increased supply of protein food.

The lichen partners. You know the gray lichens (li'kens) that grow like crusts or fringy structures on stones, fences, and trees. A lichen is not one plant but two, and one of the plants provides the food for both.

A lichen is made up of fungus filaments with an alga entangled in them. The fungus gives the lichen its shape, holds it to the tree or rock, absorbs water from the air, and keeps the alga moist. It is colorless, however, like the filaments of the bread mold and because it lacks chlorophyll it cannot carry on photosynthesis.



Lichens of various kinds. A lichen is made up of an alga and a fungus.

The two plants solve their life problems in partnership.

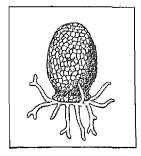
The green alga does this, making enough food for both itself and the fungus with which it lives. The alga furnishes the bread for the household and the fungus provides moisture for the alga and gives it a protected home. The fungus is really a partner and not a mere parasite that returns nothing for its keep.

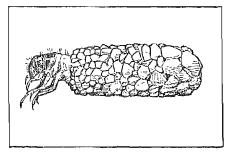
There are many kinds of lichens and each species has its own kind of fungus. In any lichens that you will find the alga will probably be Pleurococcus (you can easily decide this by picking the lichens to pieces under the microscope), but in some parts of the earth the blue-greens are the algae involved. The fungi produce spores which blow about and germinate; then if the fungus filaments can find some algal cells to enclose, a new lichen is on its way.

An artificial shell. Nature gives to many animals the protection of a shell. Other animals build for themselves out of sticks or small stones a case that gives them the same security. The larva of the caddis fly is one of these.

This larva lives in streams and ponds. It is a plant eater and it needs a defense against the many hungry carnivores that live in the same waters. The larvae of some species secure this by build-

ing an armor for their bodies out of sticks which they tie together by threads of silk. Others build a case of small stones cemented each in place so as to form a perfect covering. To move about, the little animal thrusts its head and the forepart of the body that





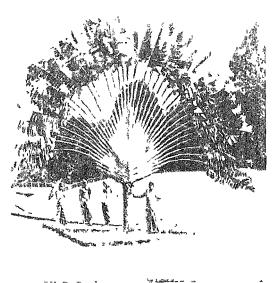
A microscopic animal (Difflugia) and an insect larva (caddis fly) that build themselves artificial protective coverings.

bears the legs out of the front opening of the artificial shell. When danger threatens it withdraws into the armor it has itself built. As the larva grows it must from time to time leave its case and build a new one.

Another animal that builds a shell for itself is the little proto-zoön, *Difflugia* (dĭ-flū'jĭ-a), which lives in fresh-water pools and ditches. It is a mere microscopic speck of protoplasm. Yet it takes up sand grains and cements them into a vase-like house in which it lives, with strands of protoplasm extending like little arms out of the open end. Although it consists of but a single cell it builds its shell with all the precision of a larger animal that has a brain and a mind.

An investigator who was raising Difflugia in his laboratory gave them only powdered glass for building use. They built the shells of the glass particles up about two thirds of the way and then stopped. When sand was provided they finished the job.

Protection against drought. In Madagascar there grows a plant that is called the traveler's palm. It is not a true palm but a member of the banana family and specimens of it are grown for ornament in many parts of the tropical world.



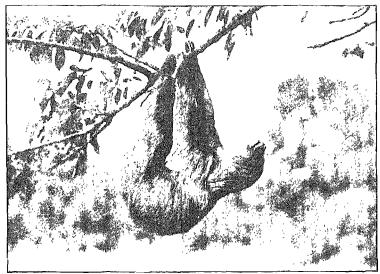
The traveler's palm. The bases of the leaves hold a reserve water supply. A plant of this size may contain 20 quarts.

The long leaves of this plant come out from the trunk in two ranks, so that the plant has a fan-like appearance. The stems of the leaves are troughshaped and each clasps the one above so tightly that water is held in the spaces between them. When it rains these water receptacles fill up. When dry weather comes the plant has this water as a reserve supply. The plant was given its name because a thirsty traveler could find water in it. A fair-sized plant will hold as much as

20 quarts. Many plants store water within their bodies, but few of them store it as the traveler's palm does.

Unusual ways of getting oxygen. The air-breathing animals that lead a water life must have ways of getting an oxygen supply and among these we find many unusual arrangements. Penguins have an air pouch in each cheek which gives them an additional air supply when they dive. Whales have a reserve blood reservoir and when the blood in this has been oxygenated they can remain under water for as long as 20 minutes. The diving beetle, back swimmer, and other insects of fresh-water pools and ponds capture air at the surface of the water and carry it with them in small bubbles under their wings or entangled in their hairs. Best of all the arrangements is that of the diving spider, which leads a regular underwater life.

This tiny spider makes for itself a silken bell and fastens it mouth down to a plant or other underwater object. It carries down to the bell enough air to fill it. It spends much of its life



New York Zoological Society

A two-toed sloth. The sloth is a treetop animal of the tropical American forests. A small alga (Pleurococcus) grows on its rough hair and gives the animal the green coloring of the leaves.

and rears its children in this small silken home to which oxygen must constantly be brought.

Protective coloration of the sloth. The sloth, which hangs in the trees of the South American forests and feeds on their leaves, is incredibly slow in its movements. It is helpless against an enemy and its only safety is in remaining unseen. It gets a protective coloring in an unusual way. The surface of the sloth's hairs is rough and Pleurococcus attaches itself to them. In the moist air of the equatorial forest the little alga flourishes and gives the sloth a green color that helps to make it inconspicuous among the leaves.

These examples of unusual methods of meeting life problems have been presented because of their interest and to call attention to the variety of ways by which organisms provide the necessities of their life requirements. Possibly a knowledge of them will stimulate you to notice the solutions the living things about you have for the important problems they must face.

APPLICATION TO MAN

Man has many needs beyond those of a simple organism. Some of these needs are secondary ones that grow out of his more complicated body structure. Others are mental and social needs that have their roots in man's more highly developed mental and emotional nature. Yet, as a physical being, man meets the same problems as other living organisms. He must have food and oxygen, as other organisms must have them. He requires protection from cold and from his enemies among other living things. Man's fundamental problems are those that relate to the satisfaction of his primary physical needs that press so relentlessly upon him. What we call "social security" could more properly be termed "physical security," for the attempt in security programs is not to provide against the taking away of social or political rights but to assure that there shall not be suffering from hunger, cold, or preventable or curable disease.

Notice how keenly men desire an opportunity to make themselves secure against physical want. Notice how many of our social and political questions trace back to the fundamental life problems that we meet in common with all other living things. Notice how men can be ruled and held in helpless subjection by those who get control of their means of life. A very common error in political thinking is a failure to appreciate the importance of economic freedom, without which no other freedom can be maintained. The right of free speech is of no value to those whose bread supply is in other hands.

Science can provide an abundance of the things necessary for the satisfaction of our physical needs and when it is employed to do this it is an instrument of liberty. If it were rightly used it could easily create such an abundance that a whole people would be lifted above the level of physical want and the conditions for true freedom established. It is the task of your generation to see that science is directed to this end.

UNIT COMPREHENSION TEST

- A. What are some of the problems that all organisms must meet?
- B. How does a green plant get food? What is the primary process in food building called? Write the equation for this process. What foods are built by secondary processes in green plants? Where does the energy come from that is stored in foods? How do animals get their food? Contrast plants and animals in their adaptations for getting and using food.
- C. How do the inner cells of a leaf obtain oxygen? How do the inner cells of a twig obtain oxygen? In what ways do the roots of swamp plants obtain oxygen? How do fishes and other water animals obtain an oxygen supply? Name three kinds of organs for taking oxygen from the air, and explain how they work. How do the insect larvae that live in water obtain an oxygen supply?
- D. What are some important methods by which plants protect themselves from other organisms? In what ways do animals protect themselves from other organisms? What is meant by protective coloration? How do animals change their colors? What is meant by disruptive coloration and what advantage is there in it? Give examples. What is meant by mimicry? Give examples of it.
- E. What are the two most important dangers of the physical environment? How do plants adapt themselves to seasons of winter cold? What are some of the ways by which animals pass the winters? How do plants adapt themselves to seasons of drought? In regions of wet and dry seasons, how do animals pass through the dry season? What is hibernation? estivation? How does an African lungfish pass through periods of drought?
- F. How is the wood which termites eat digested? How do termites secure a special food supply for the young and the royal family? What plants use living animals for food? Describe a pitcher plant and its method of food getting; the bladderwort; the sundew; Venus's-flytrap. What is a lichen? How do Difflugia and the larva of the caddis fly protect themselves? How is the traveler's palm adapted for living in dry regions? Tell about the activities of the diving spider. How is the sloth made inconspicuous in its treetop home?

SUGGESTED ACTIVITIES AND APPLICATIONS

- 1. Set a potted plant in the dark overnight. Then cover a part of a leaf with two pieces of cork (page 192), and set the plant in sunlight. After several hours remove the leaf, dip it first in hot water (to kill the cells), and then in warm alcohol to remove the chlorophyll. After the leaf is decolorized, test for starch by dipping it in a weak aqueous solution of iodin. (CAUTION. Alcohol is inflammable. Heat it by setting a bottle or flask of it in hot water.)
 - 2. Repeat the above experiment, using a variegated leaf.
 - 3. Examine the epidermis of a leaf for stomata. Draw.
 - 4. Examine a twig for lenticels.
- 5. Boil a part of the body of an insect (grasshopper, cricket, cockroach, bee) in a strong alkali (sodium or potassium hydroxide) solution. This will dissolve the muscle tissue and other soft parts. Wash with water. Then with a microscope examine the remaining tissues for tracheae (pages 333, 334).
- 6. Bring in water-living insects and larvae and study their methods of getting oxygen.
 - 7. Class projects:
 - a. Let members of the class bring in all the plants and small animal forms they find that show

protective devices or protective

coloration.

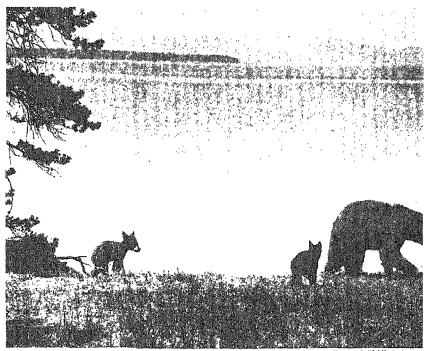
b. In shallow, air-tight boxes covered with cellophone or glass make permanent mounts of insects and other small organisms that show protective devices and colorations. Boxes prepared especially for making such permanent mounts are sold by supply houses.

c. Bring to the schoolroom and observe any kinds of carnivorous plants that grow in your region. The photograph at the right shows



Hugh Spencer

- a leaf of a pitcher plant that grows in our Eastern states. The photograph will help you recognize this plant.
- 8. Bring in resting bulbs, corms, rootstocks, tubers, and roots. The potato, onion, narcissus, jack-in-the-pulpit, iris, lily of the valley, and dahlia are examples of plants that will supply such parts.
- 9. Bring in a lichen and pick a small portion of it to pieces in a drop of water. Examine several species and see if the same alga is in each of them.



Fish and Wildlife Service

UNIT 6 METHODS AND PROBLEMS OF REPRODUCTION

Reproduction is a fundamental biological process that provides for the continuance of life.

"Life is a continuous, a never-ending stream of protoplasm in the form of cells, maintained by assimilation, growth, and division. The individual is but a passing eddy in the flow which vanishes and leaves no trace, while the general stream of life goes forward."

A GREAT LIFE PROCESS

QUESTION FOR CLASS DISCUSSION

How long should human parents support their offspring?

THE reproductive process occupies a much larger place in the biologic scheme than is generally understood. It includes not only the production of new individuals but also their nurture and the placing of them where they can care for themselves in the world. In plants it requires many structures (flowers, fruits, seeds) that are of no use to the parent organisms. In animals there must be special organs, and the reproductive process gives to birds and mammals a great assortment of sex and parental instincts that often condition the whole living plan. The general methods by which this great process is carried out in different types of organisms will be our subject for inquiry in this unit. Descriptions of the forms chosen as illustrative material will be given because to most of us it is unsatisfactory to study about a part or process of an organism when we have no mental picture of the organism as a whole.

Problems in Unit 6

- 1 What methods of reproduction do we find among the simplest green plants?
- 2 What methods of reproduction are found among the green algae?
- 3 What methods of asexual reproduction are common among land plants?
- 4 What adaptations for sexual reproduction do we find in the seed plants?
- 5 What are some of the methods employed by animals in the care of their eggs and young?
- 6 How did reproduction by gametes develop and what advantage is there in this method?

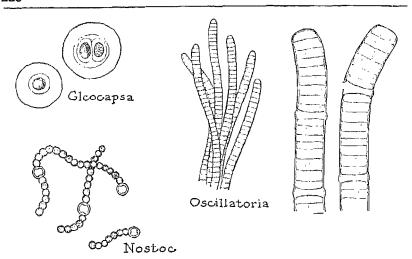
PROBLEM ONE

What Methods of Reproduction Do We Find among the Simplest Green Plants?

The simplest green plants are the algae (ăl'jē) and the simplest algae are the blue-greens (page 995). In these little plants the nuclear material of the cell is not even collected together but is scattered in granules through the cytoplasm. All of them multiply only by simple cell division. They have in addition to chlorophyll a blue pigment that gives them a blue-green appearance and from which they get their group name. Some of them consist of a single cell and some are simple chains of cells. Others are filaments in which the cells are more closely fitted together. All are microscopic in size.

Where blue-greens are found. The blue-green algae are found everywhere. They grow in immense numbers on the surface of moist soils and in the upper soil layer. They are abundant in greenhouses, and with other organisms they often form a glistening film ("water bloom") on the surface of water. They make up the dark bluish slimy growth on wet rocks, on the mud of pools, or on wet ground. Some of them can grow in hot springs that have a temperature up to 185° F. They are so tenacious of life that they have been found to be still alive in dry soil samples that had been kept in bottles for 70 years. In addition to their chlorophyll and blue coloring, some have other pigments also that give them a red or brown appearance. The Red Sea takes its name from the millions of small red-colored blue-greens that grow in its surface layer.

Gleocapsa. One of the blue-greens that you can probably find is *Gleocapsa* (gle'o-căp'sa). It grows on damp rocks and walls as little spots or patches of "blue-green slime." Examine some of this material under a microscope. If you find that it is composed of minute one-celled plants embedded in a sticky, clear, gelatin-like material, you have Gleocapsa. Each cell contains a blue pigment which with the chlorophyll gives the blue-



Three common blue-green algae. They all multiply only by division of the parent body.

green color to the growth. Like Pleurococcus, Gleocapsa multiplies by simple fission (or division) of the cells.

Oscillatoria. A blue-green form that is very common is Oscillatoria (ŏs'i-la-tō'rĭ-a). You will find this on the inside of troughs where cattle and horses are watered; on the banks of pools or streams contaminated with sewage or barnyard drainage or on sticks or stones in such water; and in greenhouses. It forms a felted dark bluish-green growth which under a microscope is found to be a mass of fine thread-like filaments. These filaments stand out like little hairs in the water and wave back and forth by their own contractions. With the low power of the microscope you can easily see in fresh growing material this oscillatory movement that gives the plant its name.

The filament of Oscillatoria is made up of a row of cells. Each cell is shaped like a thick coin. In the filament you see the edges of the cells as you would see the edges of coins in a stack. The filament grows in length by crosswise division of the cells. Under your microscope you can doubtless find thin pairs of cells that have been formed by recent division. There is no differentiation of the cells. As a filament lies in the water each cell can absorb

the materials that it needs and make its own food. Although the cells of many of the blue-greens are joined together in chains or filaments, each cell lives much as it would if it existed alone.

In an Oscillatoria filament you will often find a place where a cell has died. At this point the filament breaks apart, thus becoming two. Each part of the filament grows in length and repeats the breaking-in-two process. Thus the plant multiplies until cakes, or masses, of the filaments are formed. In Oscillatoria there are no special reproductive cells or organs.

Nostoc. Sometimes in the shallow water of swampy places you will find jelly-like bluish-green masses attached to grass or weeds. The masses may be from the size of a pea up to that of a small orange. If you crush some of the material and examine it with a microscope you will find it filled with *Nostoc*, a very fine little blue-green alga. The cells of Nostoc are in chains. They are more loosely put together than the cells in the filament of Oscillatoria.

If you examine Nostoc with a microscope you will find occasional cells that are different from the others. They are greatly enlarged and practically empty. These enlarged and transparent cells develop from ordinary cells. A cell begins to grow and after it has increased greatly in size it dies and its contents disappear. Then the chain of cells breaks in two at this point. The enlarged cells seem to be specially set aside to multiply the plant by breaking the filament into parts. In Nostoc, small and simple as the plant is, there appears to be a special arrangement for reproduction by a division of the body of the plant.

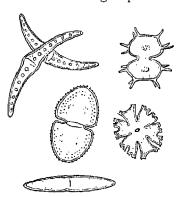
None of the blue-green algae reproduce by spores or gametes. They multiply simply by growth and division of the parent body. In them we find reproduction in only its simplest form. The yeast plant, as we have seen, and many other small organisms (bacteria, protozoa) multiply in this same simple way.

PROBLEM TWO

What Methods of Reproduction Are Found among the Green Algae?

In fresh water many kinds of molds similar in a general way to the bread mold are found. One of these grows on the skin and gills of the goldfish. Other kinds obtain their nourishment from dead organic materials in the water. If you will place a dead fly or a small piece of meat in water taken from an outdoor pool you will probably find within a few days that you have a crop of a very common water mold, Saprolegnia (săp'rō-lěg'nĭ-a). We might choose the molds to illustrate the methods of reproduction that are common among the simple fresh-water plants, but we shall select the green algae. The algae are easier to find and the reproductive processes in the two groups are essentially the same.

The green algae. You have seen masses of fine green material floating in ponds or lakes, attached to stones or sticks in



Desmids. Many kinds of these one-celled green algae grow in the waters of ponds and pools. The crescent-shaped one is Closterium.

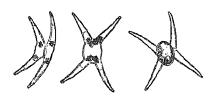
streams, or growing on the mud at the edges of pools. These are green algae. Some kinds of them are one-celled. Many are filaments. Most of them are larger than the blue-green algae. In Pleurococcus (page 105) you have studied a very successful little green alga that is found all the way from the tropics to the regions of arctic cold. Spirogyra (page 125) is a very common pond form that is quite typical of the group.

In the main the green algae are an assemblage of fresh-water

forms, although they are found also along seashores, especially in warmer waters. The most interesting thing about them is the adaptations of their reproductive methods to a water life. While not all the kinds we shall describe are abundant in every region, enough of them can be found in any place where there is fresh water to give an idea of the group.

The desmids. The desmids are a great group of one-celled green algae. They show an endless variety of design. One common kind that you will probably find in your examination of materials with the microscope is called *Closterium* (klös-tě'rĭ-um). You can recognize it from the illustration. The desmids are very beautiful and are common inhabitants of ponds and pools.

Desmids reproduce by crosswise division of the cell. They reproduce also by conjugation. Two individuals place themselves side by side. The walls between them break down and the protoplasm of the two cells flows together. In this way a spore is formed which grows into a new plant. The figure



Conjugation in *Closterium*. The protoplasm of the two cells flows together and forms a spore.

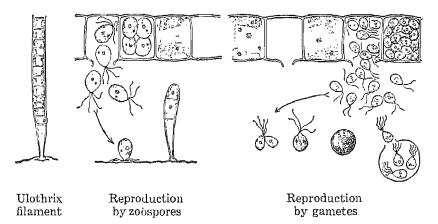
into a new plant. The figure above will make clear how the process is carried out. The spore formed is a sexual spore.

Ulothrix. Ulothrix (ū'lo-thriks) likes clean water and moving water. It grows attached to piles or rocks out in a lake where the waves break over it, in the water flowing from a clear spring, in a millrace, or in watering troughs or fountains. Each plant is a slender bright green filament perhaps 2 inches long. The cells are longer than in Oscillatoria and the filament is made up of them as a string of beads is made up of beads placed end to end. One of the end cells in the filament is differentiated to form a foot, or holdfast, by which the plant is attached to its support.

The sea lettuces are salt-water cousins of Ulothrix that are especially abundant in the warmer ocean waters. They are found as delicate green sheets of cells attached to sticks and stones on the seashore.

Reproduction by zoospores. If you place some Ulothrix in the dark for 24 hours and then bring it to the light, or if you transfer it from cold to warm water, something interesting is

likely to happen. The living material in some of the cells divides into little green bodies. These become oval in shape and develop



Reproduction in Ulothrix. The swimming spores (called zoöspores) grow directly into new filaments. The smaller gametes unite and then divide into zoöspores which produce new plants.

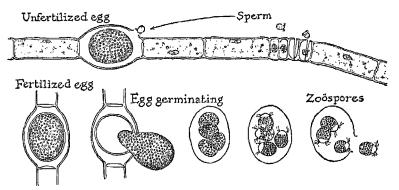
cilia (singular cilium) — little hair-like strands of protoplasm that beat the water. The little oval bodies begin to move within the cell; then the cell wall breaks open and they swim out into the water. Two, four, or eight of these little bodies may be produced in one cell. Each has a nucleus, cytoplasm, and chloroplast. Under the microscope they look like little green animals and sometimes they are so abundant that the water is filled with them. They are called zoöspores (zō'o-spōrs). What becomes of them? What do they do?

After swimming about for a time a zoöspore settles down against some object and loses its cilia. It attaches itself to the object and begins to grow and divide. Growth continues until a filament like the parent plant is formed. The zoöspores multiply the plant and by swimming to new places spread it. They are spores fitted for reproducing the plant in the water, just as the spores of the bread mold are fitted for reproducing the mold in the air.

Reproduction by gametes. Ulothrix reproduces in another way. In some cells the contents may divide into bodies still smaller than zoöspores. These also develop cilia, break out of the cell, and swim around in the water. Two of these tiny swimming cells come together and unite. The cell walls between them melt away and their protoplasm flows together. When the process is over they have been formed into one cell. This may grow directly into a new plant or it may divide into four zoöspores, each of which produces a new plant.

The small cells that unite to produce a new plant are *gametes*. They conjugate (or unite) as the gametes of Spirogyra do (page 127). The gametes seem like little zoöspores that are too small and weak to reproduce a full-sized plant, for sometimes if one of them fails to find a mate it settles down and grows into a tiny filament much smaller than the regular plant.

Oedogonium. A green alga that has filaments coarser and harsher in texture than Ulothrix is *Oedogonium* (ē'do-gō'nĭ-um). It occurs often in small pools and ditches where the water is not as clean as Ulothrix requires. Masses of it may sometimes be found on the wet earth where the water level is falling. Like Ulothrix it reproduces in two ways — by zoöspores and by gametes. In some cells the contents divide up into zoöspores which swim away



Reproduction in Oedogonium. The gametes are of two kinds. One, called the egg, gathers a heavy food supply and is motionless. The other, called the sperm, is small and motile and does the swimming necessary to bring the gametes together.

and start new plants. In other cells of the same filament or in other filaments, gametes are produced. These are not all of one size as in Ulothrix but are of two kinds, *eggs* and *sperms*.

Some cells of the filaments accumulate food materials and increase greatly in size. These large cells with their stores of food are eggs, or female gametes. They accumulate a store of food that is used in starting a young plant. Other cells of the Oedogonium filament are cut by cross walls into short sections and in each of these sections two small gametes with cilia are formed. These are sperms, or male gametes. They pass out into the water and swim about in it.

When an egg is mature an opening comes in the side of the cell wall that encloses it and through this opening a sperm swims in and unites with the egg. You will remember that the uniting of the sperm and egg is called fertilization.

After the Oedogonium egg is fertilized it becomes capable of growth. It divides into four zoöspores, each of which produces a new plant.

Reproduction in green algae. Let us now pause to consider some of the facts we have learned about the way the green algae reproduce.

- (1) Some kinds multiply by zoöspores. In the production of a zoöspore there is no union of cells. A zoöspore is therefore an asexual spore. Reproduction by zoöspores is asexual reproduction.
- (2) Some kinds reproduce by the union of gametes. This is sexual reproduction. The gametes may be equal as in Ulothrix. Then we cannot say that either one is male or female. Or one gamete may be a small active swimming sperm and the other a large motionless egg loaded with food as in Oedogonium. In Oedogonium one gamete accumulates a food supply and the other does the swimming necessary to bring the gametes together. The gametes have been differentiated into male and female.

The next step would be the differentiation of the plants into male and female so that the eggs and sperms would be produced in different plants. In some of the algae this differentiation has been made. Some of the plants are male and some female. Did you note any evidence of maleness and femaleness in the Spirogyra filaments?



Three common kinds of filamentous green algae.

Economic importance of green algae. The green algae are not only of interest because of their reproductive methods but also because of their economic importance. What do you suppose the fish of our lakes, streams, and ponds live on? On insects, worms, and other small animals. Then what do these smaller animals live on? Mainly on the green algae. These are the chief food makers for fresh-water life. They support the water animals, just as the land plants support the animals of the land. It has been found possible to increase greatly the growth of algae in a pond by adding fertilizer to the water. This increases correspondingly the amount of fish life that the pond will support.

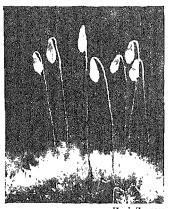
Thousands of kinds of green algae have been classified and named. In the group of pond scums alone there are more than 1200 species. Under the microscope some of the forms are very beautiful and you will find it interesting to bring specimens of the kinds that are most abundant in your locality into the laboratory and examine them for yourself. The illustration above shows three common forms. Economically the green algae are far more important than either the mosses or the ferns.

PROBLEM THREE

What Methods of Asexual Reproduction Are Common among Land Plants?

All the major groups of plants except the algae — the fungi. mosses, ferns, and seed plants — are predominantly land plants. All of them except the seed plants multiply by asexual spores. Many of them, including great numbers of the seed plants, multiply also by vegetative propagation, or division of the plant body. Among the seed plants this latter method has been worked out so well by many species that they have given up the production of seed and depend entirely on vegetative propagation. The pineapple and the banana are examples of plants of this kind. Like the human appendix their fruits are only useless relics of the past.

Reproduction by asexual spores. You have seen the spores of bread mold. They are special reproductive cells of a



Hugh Spencer

Capsules of a moss plant. Examine the contents of a causule under a microscope and you will find the asexual spores.

type that can withstand drying. They are fitted to be blown about through the air and sometimes they are carried by the winds for hundreds of miles. Most fungi produce spores of this general type by the thousands and millions. They blow about and fall everywhere. Most of them perish, but so abundantly are they produced that wherever there are room and food for a fungus a spore is likely to be there.

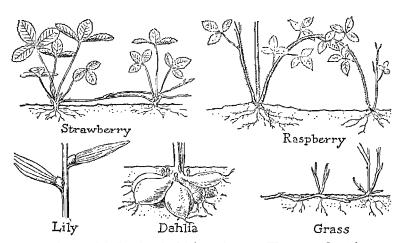
Mosses and ferns also produce asexual spores. Crush the little capsule, or pod, that grows on top of a moss plant and look at the

contents of the capsule under a microscope. You will see the moss spores. Examine steep banks and bare places on the ground and you will find moss plants starting from the spores that were blown about and fell on these spots. Tear apart the material in one of the dark spots on the back of a fern leaf and you will find that it is made up of little cases filled with spores.

All the plants up to the seed plants — except the very simplest ones — multiply by asexual spores. In land plants the spores are fitted to be blown through the air. In the green algae and some fungi that live in water there are zoöspores fitted for a swimming life. Always an asexual spore is a single special reproductive cell fitted for being liberated from the parent body and by its growth reproducing the plant.

Vegetative propagation. In a plant we distinguish between the *vegetative parts* and the *reproductive parts*. The vegetative (vegetable) parts of one of the higher plants consist of the stem, leaves, and roots. The reproductive parts include the flowers, seeds, and fruits. Vegetative propagation is the producing of a new plant from a vegetative part of a parent plant.

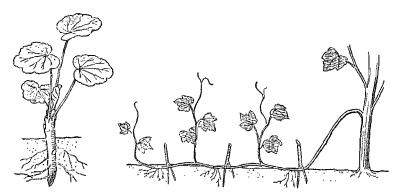
Vegetative propagation may be carried on in many ways. Shoots may spring up from underground roots or stems and develop their own root systems. A stem trailing on the ground may take root at the joints or at the tip. Special reproductive bodies may be developed like the tuber of the potato, or the little



Vegetative multiplication in higher plants. The new plant is produced from a vegetative part of the parent plant.

REPRODUCTION

bodies at the base of the leaves of the tiger lily, or the clusters of small bulbs on the shoots of some kinds of onions. Strawberries,



The young plant at the left is being started from a cutting; the plants at the right by layering.

bramble fruits (e.g., blackberry, raspberry, dewberry), currants, and gooseberries usually multiply vegetatively, as do lilies, gladioli, lily of the valley, sweet potatoes, rhubarb, and bulb and tuber plants in general.

Artificial vegetative propagation. Florists and nurserymen make extensive use of vegetative propagation in the multiplication of their plants. Stem cuttings (pieces of the stems) of geraniums, begonias, carnations, roses, and other plants are set in beds of sand or of sand mixed with peat, where they develop roots. Root cuttings, which develop buds and shoots, are sometimes used. Young grape, filbert, boxwood, wistaria, and rose plants can be started by layering (bringing a branch down close to the earth and covering it with soil). Willow trees may be planted along streams and near ponds by merely sticking the ends of willow branches into the moist soil, and poplar branches will often take root if planted in this way. The potato, sweet potato, and sugar cane are examples of crop plants that are multiplied vegetatively rather than by seeds.

Grafting and budding. By grafting and budding, the top of one plant is made to grow on the roots of another. These

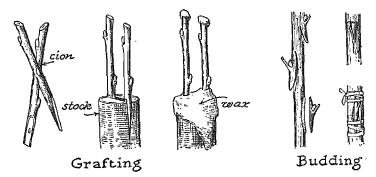
processes are used mainly for obtaining orchard trees that will bear fruits and nuts of established varieties.

In grafting, a twig from one plant is set on the stem of another. The twig is called a *cion* (sī'un); the stem to which it is attached is called the *stock*. The essential point in grafting is to set the cion in such a position that the growing layers at the inner edge of the bark will come together. This brings wood in contact with wood so that the cion can draw moisture from the stock, and when the two sets of growing cells along the inner edges of the bark multiply they intermingle and unite the cion and stock.

In budding, a single bud instead of a twig is used. A T-shaped slit is made in the bark, as is shown below. Then the bud, taken from a tree of the desired variety, is placed in the slit. Under the bark the bud finds moisture and nourishment, its cells multiply, and in time it grows firmly to the stem to which it was attached. After the bud has started into growth the natural top of the young tree is cut off.

It is the cion (or top part of the tree) that determines the kind of fruit that will be produced. The roots merely serve as gatherers of the water and food materials that the top needs.

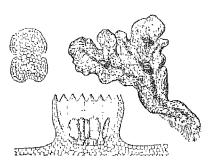
Buds and graft cions may be made to grow not only on plants of the same species but in some cases on nearly related species. A tomato can be grafted on a potato. The quince is used as a rootstock for the pear, to produce dwarf trees. The apricot can be



By grafting or by budding, the top of one plant is made to grow on the roots of another.

grafted on either the peach or the plum and the hickory grows on the rootstock of the pecan. By placing cions of different varieties on the branches of a tree like the apple or the orange it is possible to gather from one tree fruits of many different kinds. One horticulturist had an apple tree that yielded twenty-seven varieties ripening at different times.

Advantage and disadvantage of vegetative propagation. In nature plants are usually crowded and a tiny plant from a spore or seed is often overgrown before it can get a start.



Vegetative multiplication in a liverwort. In small cups on the back of the plant special reproductive bodies called gemmae are produced. A section through a cup is shown, and above at the left a single gemma. The gemmae get scattered about and produce new plants. A new plant produced vegetatively has an advantage in that it can start much more vigorously. It can draw on the root system and food supply of the parent plant until it is ready to battle its own way.

On the other hand there is a disadvantage in vegetative propagation in that plants cannot be quickly distributed by this means over a wide area. The new plant must always grow close to the parent one; there is no rapid spreading of the plant, as is possible with seeds. Never-

theless, even though the method is slow it is sure. Notice the grasses, perennial herbs, and shrubs that spread in this way. They hold the territory they have and add to it year by year.

An interesting example of vegetative multiplication. Do you know the liverworts? If you can find certain species of these you will see that not all the special devices for vegetative multiplication are among the larger plants.

These liverworts are little flat plants that grow like small pieces of green ribbon on the mud and rocks of wet places. On the top of a plant we often find the epidermis broken and raised to form tiny cups and in the bottom of the cups, each standing up on

a stalk, are *gemmae* (jem'e; singular *gemma*). Lift some of these out and put them under a microscope and you will see that each one is a little green plate of cells shaped as shown in the illustration on the opposite page. These get scattered about and the ones that find favorable conditions grow into new plants.

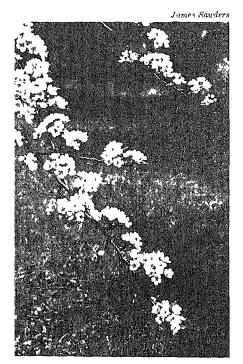
Among animals there are many examples of asexual multiplication in ways quite comparable to the methods we find in plants. These examples occur mainly among the lower water groups — protozoa, sponges, corals, jellyfishes, echinoderms, and worms. In connection with our studies of these groups we shall learn more of asexual multiplication in the animal line. In animals both the growth of a new individual from a portion of the body and the renewal of a lost body part are called regeneration.

PROBLEM FOUR

What Adaptations for Sexual Reproduction Do We Find in the Seed Plants?

Flowers, fruits, and seeds are reproductive structures and in them we find many adaptations to the biological purposes they serve. The flower is an organ to secure pollination of the pistil and fertilization of the egg. The seed is the structure through which the offspring is carried through the first stages of development and is set on its independent way. The young plant in a seed grows from a fertilized egg and therefore reproduction by seeds is sexual reproduction.

Flowers and pollination. The gymnosperms and many of the angiosperms (as forest trees, ragweed) are wind pollinated. In these plants pollen is produced in immense quantities and it is



blown about so abundantly that some grains of it are certain to fall where they can grow and fertilize the egg.

Other plants have worked out an arrangement by which the pollen is carried from flower to flower by insects. The plant has glands in the petals of the flowers that secrete nectar (a sugar solution). Bees, butterflies, and other insects visit the flowers for the nectarand some of them gather pollen also for food. In making their visits from flower to flower the insects become

The flower is an organ for securing the pollination of the pistil and the fertilization of the egg. dusted with pollen, some of which they leave on the stigmas of other flowers.

The bright-colored corolla of the flower is an advertisement that tells the insects where the nectar may be found. Perfumes guide night fliers to the food source. Small flowers often grow in heads — an arrangement which makes them more conspicuous. The biologic purpose of flowers is to attract insects and thus to secure the fertilization of the eggs from which the next generation of plants must come.

Devices for securing cross-pollination. When a pistil receives pollen from the stamens of the same flower it is said to be *self-pollinated*. When the pollen comes from a different flower the pistil is *cross-pollinated*. In flowers we find many arrangements that lead to cross-pollination rather than to self-pollination. Some of the more important of these arrangements are:

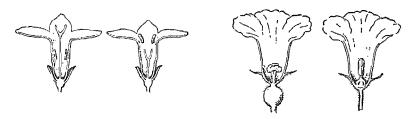
(1) Stamens and pistils maturing at different times. In many plants the stamens of a flower mature before the pistil. Then the pollen ripens and is shed before the pistil is ready to receive the pollen. In other plants the pistil develops before the stamens.

In these flowers the pistil is past the time for pollination before the pollen is ready. It will readily be seen that either of these arrangements insures that effective pollination of a pistil will be with pollen from another flower.

(2) Stamens and pistils of different lengths. The accompanying figure shows two flowers of the bluet (Houstonia). You will see that in one the pistil is long and the stamens are short and in the other the stamens are long and the pistil is short. The partridge berry, the swamp

The honeybee is the most important of all the pollen carriers. It is probably the most useful of all animals to man.





Devices to secure cross-pollination in the flowers of the bluet and of the squash. In the bluet the stamens and the pistils are of unequal length. In the squash they are in different flowers.

loosestrife, and the English primrose (cowslip) have flowers of this type.

When a bee visits such flowers it gets two bands of pollen on its body, one from the short stamens and one from the long ones. As the bee flies from flower to flower the pollen from the long stamens is rubbed off on the long pistils and the pollen from the short stamens on the short pistils. The result is cross-pollination.

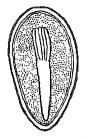
- (3) Stamens and pistils in different flowers. In a begonia the stamens are borne by one flower and the pistil by another. On a cornstalk the staminate (stăm'ĭ-nat) flowers are on the tassel and the pistils are in the ear. Such an arrangement, of course, makes self-pollination an impossibility. Oaks, nut trees, and willows are examples of plants that have their stamens and pistils in different flowers.
- (4) Stamens and pistils on different plants. There are species of plants (as persimmon, bittersweet) in which staminate flowers are borne on one plant and pistils on another. This arrangement may be compared to the separation of the sexes in animals. It insures cross-pollination not only between different flowers but also between entirely separate plants. Although it is not a very common arrangement many examples of it may be found.
- (5) Self-sterility in plants. Many plants are self-sterile, which means that pollen from their own stamens will not grow on their pistils. There is something in the protoplasm of the plant that prevents the development of its own pollen and yet allows the

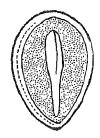
development of pollen from another plant. This again is a method of making sure that the two strains of protoplasm united in the fertilization of the egg shall not be from the same plant. Cross-pollination in a surprising number of plants is insured in this way. Filberts and some kinds of apples and pears will not set fruit unless pollinated by another variety.

These are a few of the general methods by which cross-pollination is secured. There are, of course, arrangements for self-

pollination also; and many of the self-pollinated plant species seem to continue their growth as vigorously as the cross-pollinated ones. Probably for continued vigor some lines of protoplasm require union with an outside strain and some do not.

Seeds. Seeds vary greatly in structure, but each one contains a young plant and a store



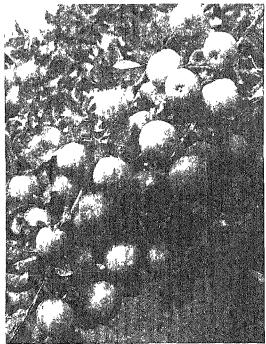


Seed of the pine (left) and of the violet. In each is a young plant surrounded by a supply of food.

of food that the plant can use in its early growth. Most seeds have a protective covering, which may be stony as in nuts or in the seed of a peach or plum. A grapefruit seed or an orange seed shows very clearly the typical seed structures. Cut one open and you will find the embryo plant lying in the midst of its store of food.

Within a seed the young plant may be very small or it may grow until it fills up the whole seed interior. A grain of corn consists of a small embryo near the point of the grain and a large amount of food that the plant can use in future growth. In contrast a bean or a pea is little more than a young plant with a covering about it. The food is stored in the *cotyledons* (kŏt'i-lē'duns) or first leaves of the little plant. Each half of a split pea or bean is a cotyledon. The rest of the embryo plant lies between the cotyledons, near one end.

The tobacco plant and many weeds produce very small seeds and thousands of them. On the other hand the coconut palm



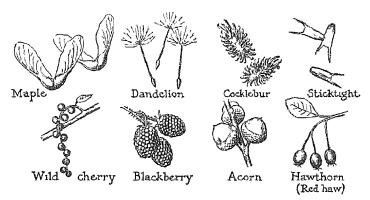
irthur M Prenti

Fleshy fruits attract animals that carry them away and scatter the seeds the fruits contain

has a giant seed—the coconut — with a great store of food for the young plant. Some plants produce thousands of offspring, give them slender resources, and throw them out with the chance that only one in a multitude will survive. Other plants produce fewer young but give them better equipment for getting started, so that the chances of the young plants for survival are correspondingly increased.

Adaptations for seed dispersal. Seeds and fruits show many de-

vices that help in getting the seeds distributed. The seeds of the ash, maple, and pine have wings. They are carried by the wind and we find the young of these trees coming up over vacant fields far from the parent trees. Dandelion, goldenrod, and milkweed seeds are equipped with hairs that serve as parachutes to carry them to new places. Tumbleweeds roll across fields before the wind, scattering their seed as they go. Burrs and stick-tights cling to clothing and to the hair of animals, thus traveling to new locations. Fleshy fruits attract animals that scatter the seeds in the fruits; squirrels bury nuts and forget them: jays drop some of the acorns that they carry away. Some of the seeds in fruits that are eaten by birds have coverings so hard that they pass through the digestive tract unharmed. The mistletoe is planted by birds on the branches of trees, and cedars from bird plantings spring up in rows along fences on which the birds perch. Doubtless you are familiar with methods of seed distribution that have not been mentioned here.



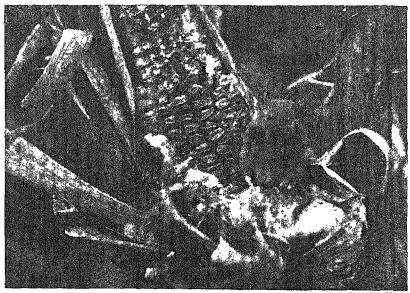
Seeds equipped for dispersal by various methods.

Dispersal of plants in time. Seeds distribute plants not only in space; they distribute them also in time. Many plants produce seeds that ripen before the end of summer. These seeds fall to the earth but do not germinate. They lie dormant until they have been subjected to the freezing of winter. Then when spring comes they germinate and start the young plants. They carry the plant through the unfavorable period for growth and start it growing at the right time.

Other seeds may have coats so resistant to the entrance of oxvgen and water that they lie dormant longer than one winter. The cocklebur produces seeds of this type. In each of the spiny pods of this plant there are two seeds, one of which germinates the first spring while the other must have an additional summer of weathering and a second winter of freezing before it begins growth. By this arrangement a cocklebur makes a planting of its seed that is good for two years. If anything happens to the plants of the first year the seeds that delay their germination are there to carry on the species the next year. Many plants produce seeds that lie dormant for one or more years. To cause sweet clover and lespedeza seed to germinate promptly they are often "scarified," which means that they are put through a machine that crushes them slightly and breaks the outer coats. In some other kinds of seeds the dormancy is broken by treating them with chemicals or by placing them in cold storage.

The time that embryo plants may remain alive in seeds is surprisingly long. Weed seeds buried for many years have in some instances sprung into activity when uncovered by excavations. Live seeds of old varieties of tobacco that had been lost from cultivation were found by plant breeders in the soil under old houses in Cuba. The record for longevity in seeds is held by water-lily seeds from the bed of an old Manchurian lake. The lake was filled with blown sand, and it was established that this occurred about 400 years ago. A botanist digging in the old lake had found the seeds and wondered if they would grow. He placed them under proper conditions and they promptly germinated. How old would a plant grown from one of these seeds be one year after the germination of the seed?

Protection of seeds from animals. Plants accumulate in their seeds stores of food on which their offspring live while they are getting a start in the world. Animals appropriate these stores to their own use. Prominent among the

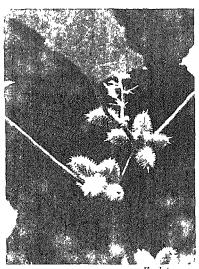


Cornelan Clarke

This little mouse has been living on the food that the corn plant stored in its seeds.

mammalian seed eaters are the small rodents (mice, rats, squirrels). Many small birds are also seed eaters, while among insects scores of kinds of weevils develop within seeds and subsist by feeding on the food supply about them.

Many plants have devices for protecting their seeds from the animals that would devour them. Fruits in general have a bitter or sour taste until the seeds In some plants the mature. seeds or fruits are poisonous. Some seed pods protect their contents by spines. In general, the seeds of plants are much bet-



Hugh Spencer

The spiny pods of the cocklebur protect the seeds within from the fate which the corn grains met.

ter protected than the vegetative parts. This is in keeping with Nature's care for the race.

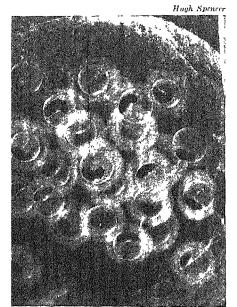
Study the whole subject of the production of new plants by seeds and you will find special adaptations by the score. of these adaptations are in connection with animals, for plants and animals are companions in the world and have innumerable relationships. There are few biological associations more highly specialized than those between the higher plants and the flying insects that pollinize their flowers.

PROBLEM FIVE

What Are Some of the Methods Employed by Animals in the Care of Their Eggs and Young?

The protozoa multiply by simple cell division; some of them reproduce by asexual spores; some of them conjugate as the desmids do. Among them we find every asexual reproductive method employed by the simpler plants and it would be possible to trace the gradual development of sex in the protozoa as we have traced it in the algae. Our present interest, however, is in the reproductive methods of animal forms above the protozoa. Our problem calls for a consideration of how animals care for their eggs and provide for the protection and nurture of their young.

Fertilization of eggs. Among the great mass of water animals of the lower phyla the eggs are fertilized in the water. Both eggs and sperms are discharged into the water and the motile sperms swim to the eggs and unite with them. The eggs of

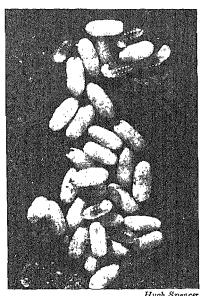


such animals as sponges, jelly-fishes, corals, starfishes, and oysters are thus fertilized. Although the method is best suited to stationary animals the eggs of many fishes also are fertilized in this way. The males accompany the females to the breeding grounds and when the eggs are laid the sperms are discharged among them.

In contrast with this method

Salamander eggs in which the young are beginning to develop. Most animals that lay their eggs in water deposit a great number of them and leave the eggs and young to their fate. is the fertilization of the eggs within the body of the mother. This method is followed by some water animals, by many worms, and in general by land animals. It is universally employed among insects and the higher vertebrates. By its use the danger of the eggs' perishing for lack of fertilization is greatly reduced.

Care of the eggs. Among the water animals the usual plan is to turn a great mass of eggs loose in the water and trust to chance that some of them will survive. The oyster, which lays several million eggs and leaves them floating in the water, is an example of an animal that follows this plan. The jellyfishes. marine worms, sea urchins, crinoids, and the great mass of lower

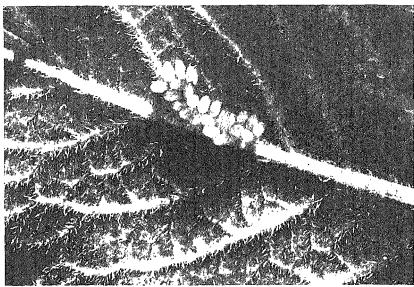


Hugh Spencer

Larvae and pupae of ants. adult ants feed the young and look after them carefully. Turn over a stone or a board under which a colony of ants have their home and you will see the workers trying to carry the eggs and young to safety.

water forms discharge their eggs and leave them to their fate. On the other hand among many of the members of the higher animal phyla the eggs and young are protected in one way or another by the parents. The mother crayfish (also the lobster) glues the eggs to her swimmerets and keeps them supplied with oxygen by slowly folding up and extending the abdomen as she rests in the water. The myriapods (thousand-legged worms) remain by their eggs and guard them until they hatch. Some mother spiders carry their eggs about in cocoons. Some fish build nests and protect them. The male of the African lungfish scrapes out a place for the eggs in the mud at the bottom of the swamp in which it lives and keeps stirring the water gently over the eggs so that they will get air. Birds, as all know, build nests in which the eggs are kept warm, and among practically all land

REPRODUCTION



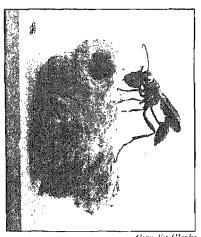
Hugh Spencer

Eggs of the Colorado potato beetle on the underside of a potato leaf. The mother beetle placed the eggs where the young on hatching would have a food supply.

animals there is an instinct to bury or hide the eggs or to place them in a favorable location. This is made necessary by the land environment. A part of the eggs of a starfish turned loose in the sea may be able to survive, but if a grasshopper did not bury its eggs they would probably all perish.

One important method of protecting the eggs and the immature young is by their retention in the body of the mother until the embryo has developed for some time. In these forms we say the young are "born alive." Some scorpions, some snails, some fishes (e.g., guppies), some snakes, and all mammals except three species give birth to live young. By "live young" we mean merely young that have undergone a considerable degree of development and show that they are alive by movement and the taking of food. In reality eggs laid in the one-celled stage are as much alive as an animal born at a more advanced stage of development.

Food supply for the developing embryo. Eggs contain not only the germ cell that grows into the new organism but also enough food to allow the embryo to reach a certain stage of growth. Then either the young organism must be able to get its own food or the parent or parents must provide food for it. Some of the young of water animals seem able to fare for themselves while still very small, but there is less wastage of new life if the food supply is sufficient to maintain the embryo until it reaches a considerable measure of matu-



Cornelia Clarke

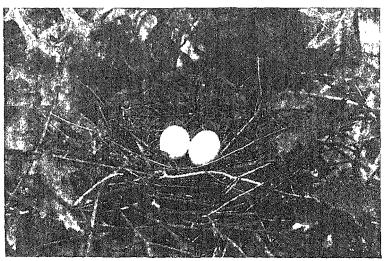
A mud-dauber wasp and its nest. It filled the mud compartment with spiders and laid an egg on top of them. It has now brought a pellet of mud which it will use in closing the nest.

rity before it ventures forth. This food supply is provided by a number of methods.

One way is greatly to enlarge the egg and the food store in it. This is done in reptiles and birds. The young of some of these develop within the egg until they can run about and search for food as soon as they are hatched.

Another method is to deposit the eggs where a food supply will be available to the young as soon as it comes from the egg. The housefly, which lays its eggs in organic waste material, and other flies, which deposit their eggs in mushrooms or meat, are examples of animals that insure a food supply for the young in this way. The tachina (tak'i-na) fly and other insects that lay their eggs on or in other living animals so that the young can live parasitically are other examples that fall under this plan.

Still another example of the food-deposit plan is furnished by the mud-dauber wasp, whose nest is shown above. This wasp builds a tube of mud and then goes forth in search of spiders. These she paralyzes by stinging and then she carries them to the



L. W. Brownell

Birds lay relatively few eggs and look after them and the young carefully. Most of them build nests. The illustration shows the nest and the eggs of a dove.

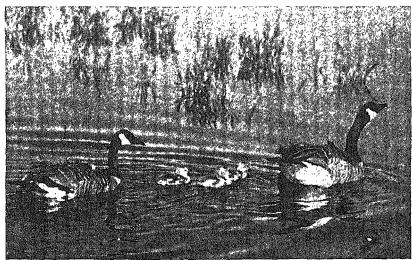


Allen Proces

Birds are warm-blooded and the eggs must be supplied with heat. The parent birds incubate the eggs by the warmth of their bodies. The photograph is that of a hooded warbler on its nest.

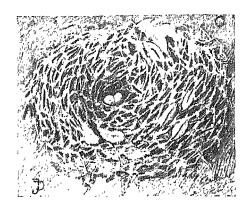
mud cell and stores them there. When the cell is filled with paralyzed but still living spiders the mother wasp lays an egg on top of the collection and closes the earthen tube. In due time the egg hatches into a larva which feeds on the spiders, goes through its metamorphosis, and comes out a mature wasp. Other kinds of the solitary wasps dig burrows in the ground and store caterpillars, flies, or other insects in them. The social wasps (those that live in colonies) bring in food and feed the young as they grow.

The bird way. Birds and mammals are warm-blooded and besides the problem of protecting the eggs and nourishing the young they have the additional problem of keeping them warm. Most birds build nests for their eggs and practically all of them incubate the eggs by the warmth of their bodies. Some of the young hatch in a naked and helpless condition and the parent birds of these species feed them until they are ready to fly and care for themselves. Our songbirds rear their young in this way.



Fish and Wildlife Service

Canada geese and goslings. The young of many of the swimming and running birds are able to accompany their parents soon after hatching. Instead of bringing food to their offspring in the nest the parents take them along.



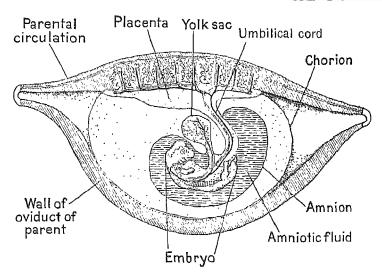


Nest and eggs of a platypus (left), and a mother platypus on her nest. The early mammals were egg layers, like the reptiles and the birds. The platypus sticks to the old way.

Both the male and the female bird work in carrying to the baby birds the insects that are practically their only food. Many of the young are almost full-grown in size before they are feathered and ready to leave the nests.

Other young birds (e.g., quail, chickens, geese, rails, killdeer) are feathered at hatching time and are able at once to follow the mothers about. The mothers help them to find food, try to protect them, in many cases cover them at night; but they rear them by taking them along as companions and not by feeding them in the nest. These birds are running or swimming birds whose young are able to get along for a time without flying.

The mammalian way. It is in the mammals that we find the highest specialization in reproductive methods. In them there are organs (mammary glands) which secrete a special food (milk) for the young. There are also other special arrangements among the mammals for the development and care of the young. The Prototheria lay eggs as reptiles do. The eggs of the platypus are incubated in the manner shown above. In the Echidna (page 424) the egg is transferred to a pouch on the abdomen of the mother, where, after hatching, the young remains until it is old enough to come out and move about.



Method of nourishing the embryo in a higher mammal. A connection is established between the blood circulation of the embryo and the tissues of the mother. Through this connection the embryo receives its nourishment.

The young of the marsupials also spend their early infancy in the mother's pouch. They are born in an immature condition and as they grow larger they leave the pouch from time to time, returning to it as they have need for protection, nourishment, or sleep. These mammals, like some of the birds, take their young with them instead of leaving them in a den or nest.

In the higher mammals a special method of nourishing the young before birth has been developed. The embryo is wrapped in a membrane called the placenta, which becomes united with the tissues of the mother, as indicated in the figure. Through this connection the embryo secures food and oxygen from the blood of the mother during early stages of its development. This is a highly specialized and a most effective method of guarding the young and nourishing it through the early stages of its life.

The young among the different species of the placental mammals are born in very different stages of maturity and the parents care for them in many different ways. Most rodents (e.g., rats, mice) are at birth blind and helpless and are cared for by the mother in a nest or burrow. The carnivores (e.g., cats, dogs, bears) also are born blind and are cared for in dens. The young of the hoofed animals (e.g., deer, cattle, horses) are ordinarily born only one at a time and they are well developed at birth. The mothers may leave them hidden in the grass or bushes at first, visiting them from time to time, but soon the young are able to join the adult animals and run with them if an enemy pursues.

When we come to the monkeys and apes we again find a group of animals whose young are born in a helpless condition; but these animals have no dens or nests or other fixed homes and must carry their babies with them. This they are able to do because the mothers have arms and hands and also because the young, immature as they are, have strong grasping power and the instinct to cling to the mother as she climbs and walks about. Monkey and ape mothers are kind and attentive to their babies and they are successful in raising a high percentage of them to maturity.

No field and woodland schools. It is often assumed that birds teach their young how to fly or swim and that the wild mammals of the fields and woods put their children through a course of training to fit them for their particular mode of life. This idea is a mistaken one. The animals below the great apes allow their young to act instinctively or to find out how to do things for themselves. The parents accept no responsibility for the way their offspring turn out in life. Among the animals of our fields and woods there are no schools.

The instincts that enable animals without instruction or experience to care for their offspring are a main feature of nature's provision for the survival of the race. They are inherited as rigidly as heads or feet. Each species looks after its young in its own way.

PROBLEM SIX

How Did Reproduction by Gametes Develop and What Advantage Is There in This Method?

Sexual reproduction is by gametes. Two cells fuse and the product of the union grows into a new organism. Reproduction in this way occurs in all the major plant and animal groups except in the simplest forms like the bacteria and the blue-green algae. It has been worked out in so many groups of organisms that it must have a deep biological meaning. Yet there are so many exceptions to any general statements that we can make about the meaning of the process that we find it difficult to set forth its significance with any conciseness. Because we have not yet studied the simple animal forms we will base our study in large part on what we have observed in plants. In science we know only what we learn from facts and the discussion will be in the main a review of familiar facts from a special point of view.

Development of sexual reproduction. The bluegreen algae and Pleurococcus multiply by simple cell division. Among somewhat higher forms of algae (e.g., Ulothrix, Oedogonium) we find that asexual spores (zoöspores) are produced. These are special reproductive cells, each of which grows into a new plant.

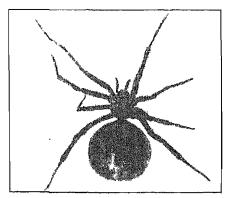
We find also that in many forms gametes are produced and that there is a fusion of two of these before the new plant is pro-

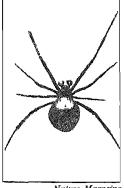


An unmated Spirogyra cell may, without union with another cell, produce a spore. A study of the lower forms of life seems to indicate that the gamete has developed out of the asexual spore. Conjugation or fertilization appears to be a pooling of the resources of two reproductive cells for the production of a new organism.

duced. The gamete seems to develop out of the asexual spore. If a gamete of Ulothrix does not find a mate it will settle down and grow into a dwarf filament. An unmated Spirogyra cell in a reproducing filament may by itself produce a spore. Sexual reproduction in the algae therefore seems to arise by two reproductive cells' fusing and thus pooling their resources for the production of a new plant. If two zoöspores were to unite before beginning growth and division we should call them gametes. A gamete of Ulothrix seems much like a zoöspore except that it is smaller and unites with another gamete before growing into a new plant.

The next step in the development of the sexual reproductive process is the differentiation of the gametes. One becomes the egg — or female gamete. The other develops into the sperm or male gamete. Oedogonium and many other algae show the differentiation of gametes into eggs and sperms. This condition of differentiated gametes is found in mosses, ferns, and seed plants and in all animals above the protozoa. It seems to be a very advantageous arrangement to have one gamete gather a food supply that will give the new organism a good start and the other gamete do the swimming that brings the two together. The plan of having one of the gametes provide an abundant food supply reaches its climax in the large eggs of reptiles and birds.





Nature Magazine

The female and the male black widow spider. Among the spiders the female is the larger.



New York Zoological Society

Lion and lioness. In mammalian species the male is often the larger.

Development of sex. The final step is the differentiation of the parent organisms into male and female — into one form that produces only sperms and another form that produces only eggs. This has been done consistently only in the higher animals; the usual condition is the *bisexual* one. Nearly all plants and most of the lower animals have both male and female organs and produce both eggs and sperms. Sponges, starfishes, and earthworms are examples of animals that are both male and female.

In the arthropods and vertebrates, however, and in some animals lower down, there is a separation of the sexes. Some individuals produce only sperms and others produce only eggs. This often gives what amounts practically to two kinds of animals of the same species, for there may be a decided difference in the size and appearance of the male and female of the same species. The female of the toad, for example, is much larger than the male, and the males in many species of mammals decidedly excel the females in size and strength. Examples of these sexual differences are shown in the illustrations. Nature has produced not

only a million kinds of animals but in many species a male and a female of each kind.

Although in the higher animals differentiation into males and females is universal it is evident that the bisexual condition is the original one. In the embryos of the higher animals a set of both male and female sex organs begins to develop. Then one of these sets of organs is suppressed (fails to develop) and the other goes on to full development. The remnants of these suppressed organs often persist, as in the rudimentary mammary glands that are present in the males of mammals.

There is a record of a fowl that developed as a female and then turned into a male. Tuberculosis destroyed the ovary and then the male gland developed and the fowl changed its sex. As a hen it laid eggs and became the mother of chicks. Later as a cock it became the father of chicks. Such happenings are part of the proof that the bisexual condition is the original one and that maleness and femaleness have been reached by a suppression of one set of the sex organs.

Significance of sex. What is the meaning of sex? What biological purpose does it serve? These are hard questions.

One benefit of conjugation or fertilization is supposed to be that it results in the rejuvenation of the protoplasm. It is believed that many lines of protoplasm after a number of cell generations tend to become feeble (to "run out") and that the union of two lines of protoplasm gives renewed vigor. The belief is that greater vigor results if the two lines of protoplasm are not closely related. Cross-breeding of plants often gives "hybrid vigor" and the introduction of "new blood" in the breeding of domestic animals is often advisable.

There are objections to this point of view. *Paramecium* (păr'a-mē'shĭ-um), a protozoön (page 272), has been cultivated for two thousand generations without sexual reproduction and without loss of vigor. Bacteria and the blue-green algae grow on and on without sexual reproduction. Some of the higher plants do the same. Many plants (e.g., bean, pea, many grains and grasses) are self-pollinated and the eggs of many bisexual



Journal of Heredity

Hybrid vigor. Each photograph shows two parent species of Kaffir corn with their larger hybrid offspring between them.

animals (e.g., tapeworm, some species of snails) are fertilized by sperms from the same animal. Yet these facts probably do not invalidate the theory that in many strains of protoplasm cell union is necessary for the continuance of vigor. In plants, as we have seen, there are many devices that insure cross-pollination. In the higher animals the separation of the sexes makes sure that the gametes shall not have the same origin. The result of the whole scheme of sexual reproduction is to bring about a fusion of two protoplasmic strains in each individual and in many strains this fusion is probably necessary for the continuance of growing power.

A second advantage of sexual reproduction is that it gives new combinations of protoplasm and new kinds of organisms. It makes possible the advance of life by providing the variations from which new and higher forms can be selected. The details of this topic belong under a discussion of heredity and we shall consider them in a later unit.

Parthenogenesis. With a razor blade shave off the top of a dandelion bud so that you remove the stamens and pistils of the flowers. There is now no possibility that the flowers can be



Charles Leroy Parmenter

A fatherless frog that lived to the age of fourteen months. The development of the egg was started by smearing it with blood and pricking it with a needle. pollinated or the eggs fertilized. Yet the seeds will develop. The fact is that the pollen of the dandelion is defective and the seeds always develop without fertilization. Seemingly at one time the dandelion had sexual reproduction and gave it up. The egg forms, but it grows into a new plant without union with a male cell. This growth of an egg into a new organism without fertilization is called parthenogenesis (par'the-no-jen'e-sis).

Parthenogenesis is known to occur in a number of seed plants and also in animals. In the honeybee the unfertilized egg develops into a male — or drone (page 751). Among certain plant lice only females appear all summer

long and the eggs develop parthenogenetically. In the autumn some of the eggs develop males and then fertilized eggs are laid, which go through the winter. In the following spring these fertilized eggs again start the summer procession of females. Again the eggs develop parthenogenetically and produce only females, except at the close of the summer months.

By treatment with chemicals the eggs of starfishes, sea urchins, and a number of other animals can be made to begin development without fertilization. One scientist has caused the development of unfertilized rabbit eggs by subjecting them to heat and cold and has thus raised parthenogenetic rabbits. The illustration shows a frog that developed without a father. These happenings seem remarkable, but biologically they are no more remarkable

than the development of an individual plant from an asexual spore or the development of a bee or a dandelion from an unfertilized egg.

The answer to the question stated in this problem seems to be that sexual reproduction arose by the union of two asexual reproductive cells and that it is advantageous because it adds vigor to the protoplasm and provides for more variety in the offspring. In the struggle for existence, generally speaking, only structures and arrangements advantageous either to the individual or to the race are retained. The very wide occurrence of the sexual method of reproduction in the plant and animal kingdoms seems in itself to be evidence that there are great advantages connected with it.

NATURE'S CARE FOR THE RACE

"So careful of the type —
So careless of the single life."
ALFRED LORD TENNYSON

The purpose in this unit has been to emphasize the fact that as part of the general biologic plan all organisms are faced with the common problem of finding a way to leave offspring to take their places in the world, and to note some of the more general methods by which the difficulties in doing this are met. Nature is interested not only in the survival of the individual but also in the preservation of the race, and the scheme of reproduction holds a large place in the affairs of living things. The first business of life is to survive, and by passing from individual to individual life has been successful in surviving on the earth through a period of a billion years.

In succeeding units we shall make further studies of various plant and animal groups, and we shall note how different types of organisms attempt to maintain individual survival and to secure race survival. Practically all the activities of plants and lower animals are devoted to these ends. Their organs and physiological processes are adapted to these purposes. The instincts of the higher animals cause many of them to devote much of their lives to the care of their young.

A point to be noted in connection with this topic is that no matter what variation there may be in the way the reproductive process is carried out, reproduction is always a process of growth. A single cell or a group of cells is separated from the parent body and by growth this develops into a new individual. The reproductive process provides opportunity for further growth of protoplasm that already exists. In it there is no creation of new life. In 1794 Erasmus Darwin wrote: "Owing to the imperfection of language the offspring is termed a *new* animal, but is in truth a branch or elongation of the parent."

UNIT COMPREHENSION TEST

- A. What are the simplest green plants? Describe Gleocapsa; Oscillatoria; Nostoc. How do all these plants multiply?
- B. How do the green algae differ from the blue-greens? Describe the desmids and tell how they reproduce. Describe Ulothrix and Oedogonium and the reproductive methods of each. How do the gametes in Oedogonium differ from the gametes in Ulothrix? What is the large gamete called? the small gamete?
- C. What is vegetative propagation? What is an asexual spore? Give examples of plants that produce such spores. In what ways is vegetative propagation carried out in nature? How does man propagate plants vegetatively? How are grafting and budding carried out? What are the advantages and the disadvantages of vegetative propagation? What method of vegetative propagation is found in some of the liverworts?
- D. What are the reproductive parts of a flowering plant? What purpose do the nectar, perfume, and bright colors of flowers serve? What is self-pollination? cross-pollination? How is self-pollination in flowers prevented? What is the biologic purpose of the seed? Mention devices to secure seed distribution. What is the advantage of delayed germination? How long have seeds been known to remain alive? How do plants protect their seeds from animals?
- E. How do the lower animals care for their eggs? In what ways is a food supply provided for the embryo? How do the birds provide food for the embryo and the warmth necessary for the growth of the young? How do the most primitive mammals start their young in the world? How do the marsupials care for their young? How, in placental mammals, are the young nourished and protected during their early life?
- F. What conclusions can we reach as to the origin of gametes? What is the evidence for this conclusion? In what algae are the gametes equal in size? What is the next step in the development of sexual reproduction? What are the female and male gametes called? What is a bisexual animal? Is the bisexual or the unisexual condition usual among animals? In what phyla is the unisexual condition universally found? What are two biologic advantages in the union of two lines of protoplasm? What is parthenogenesis? What examples of parthenogenesis can you name?

SUGGESTED ACTIVITIES AND APPLICATIONS

1. Bring in Oscillatoria and examine it with a microscope. Place some of the material with projecting filaments in water in a watch glass and with the low power watch the waving of the filaments.

Look for places in a filament where two cells are unusually short. This indicates recent division. Note also places where a cell has died and the filament will break apart, thus multiplying the plant. The rounding out of cells at the ends of filaments indicates pressure ("turgor") within them.

- 2. As available material will allow, study different forms of green algae and their reproductive methods.
 - 3. Crush a moss capsule and examine the spores.
- 4. Observe methods of vegetative propagation of plants in nature. If you have opportunity to do so, practice some of the methods of artificial vegetative propagation described in the text.
- 5. Learn to recognize liverworts and try to find some with cupules and gemmae. Examine the gemmae with the low power of the microscope.
- 6. Let the class bring in as many kinds of flowers as possible and examine them for devices to prevent self-pollination.
- 7. Examine orange, apple, pea, corn, and other seeds to find the embryos within them.
- 8. Let members of the class bring in seeds and fruits showing adaptations for dispersion.
 - 9. Look for galls on plants and examine them for insect larvae.
- 10. Write a report of any observations you yourself have made relating to the care of the eggs and young by animals.
- 11. Cut off the top of a dandelion bud in such a way as to remove the stamens and pistils. Do the seeds develop? Plant the seeds and see if they will germinate. A potted dandelion may be used for the experiment.
- 12. Do you know any water animals except water-living mammals that feed their young?

Reference

TIFFANY, LEWIS H. Algae, the Grass of Many Waters. Charles C. Thomas, Publisher, Springfield, Illinois; 1938.

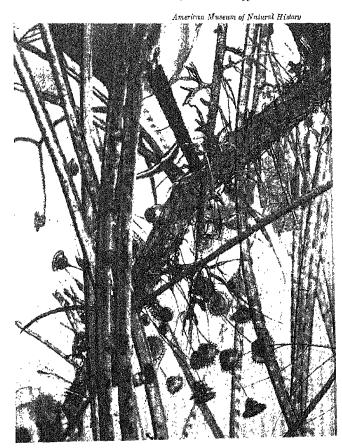
unit 7

A STUDY OF SIMPLE ORGANISMS

In its lower levels life displays itself in many forms.

"The simple organisms present us with the problems of life in their most rudimentary form. Hence they may afford a kind of key to the more elaborate organization of the higher types."

SEDGWICK and WILSON, General Biology



STUDY OF GROUPS AND REPRESEN-TATIVE FORMS

OUESTION FOR CLASS DISCUSSION

What kind of information about animals and plants is most interesting to you?

IN THIS unit we begin a series of studies from a somewhat different point of view. Instead of discussing principles and processes we shall study representative organisms and the characteristics of the groups to which these forms belong. The living creature as a whole is the center of attention; all its parts and processes as they express themselves in a complete being and not some particular selected organ or activity is the theme. The idea is to study plants and animals as we meet them in the world. Biology is the science of life, and organisms live as wholes and not as parts.

One reason for this approach in biological studies is that the primary interest of most of us is in the whole living plants and animals, and not in their parts and processes or in biological laws that have been learned by a study of them. We go to the zoo primarily because we like to watch the monkeys and to see the elephant and the tiger, and not to make scientific comparisons and observations. We read books about other living things because we are interested in knowing what they are like and how they meet their life problems. A biology course is made more interesting by information about particular individual living forms.

A second reason for studying whole living plants and animals is that such studies make biology more real and concrete. Reading the biographies of important individual men and women gives meaning to history. So, knowing about particular plants and animals gives reality to the laws and principles of biology and helps us to see their applications in real life.

The biological idea that has most influenced human thinking is the theory of radiative adaptation — that the higher organisms have developed out of the simpler ones and that this process of change and development is still going on. Nothing else gives quite the same basic grasp of this idea as arranging the groups in accordance with their natural relationships and studying the development of new features as the groups diverge.

In your examination of materials you will of course meet many forms not mentioned in this book. Your teacher will know some of these, but no one can be familiar with more than a few of the hundreds of thousands of different plant and animal kinds. Many of your specimens you can identify by using books that treat of special groups. If you have access to a museum, you will find in it a wealth of material already prepared for observation and scientifically classified. Do not be disturbed if you cannot always be sure of the species of a specimen. It is something to know that a tree is a maple or a poplar, even though you do not know which particular species it is.

Problems in Unit 7

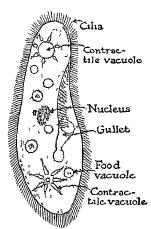
- 1 What kind of organisms are the simplest animals?
- 2 What small organisms are there that are difficult to classify as either plants or animals?
- 3 What is the plan of organization and mode of life of the sponges?
- 4 How do the fungi meet their life problems?
- 5 What new plan of body organization does the hydra introduce?

PROBLEM ONE

What Kind of Organisms Are the Simplest Animals?

The simplest animals, like the simplest plants, consist of but a single cell. They are called *protozoa* (singular, *protozoon*). They are abundant both in fresh water and in the sea. The easiest way to get them for study is to raise them.

Place a handful of hay (or dead leaves or grass) in each one of several jars. Then bring in water from different ditches, pools, or ponds and pour it over the hay. Soon an abundant growth of bacteria will appear, and following the bacteria and in large part feeding on them will come a whole swarming jungleful of pro-



Paramecium, showing the body parts.

tozoa. An examination of these little animals under the microscope will prove as interesting as a visit to a zoo. Most of them feed on bacteria and other small plants or on dead organic matter. Many live in part by absorbing food directly from the water — by soaking up molecules that come from decaying organic matter in the water. Some are flesh eaters, ranging like leopards or tigers among the more peaceful kinds.

Paramecium. One protozoön that is certain to be present in your culture is *Paramecium*. This little animal is very large for a single cell, being just

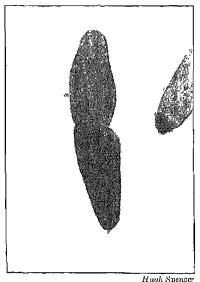
visible to the unaided eye. It is boat-shaped and under the microscope you can see it shoot about through the water, swimming in circles and turning over with a spiral movement as it goes forward. Its body is covered with cilia that lash the water like tiny oars and drive the animal about. Often the paramecium is called the "slipper animalcule" (ăn'i-măl'kūl). It is slipper-shaped, and "animalcule" means "little animal." Mounting paramecia in water to which gum acacia has been added slows their movements and makes it easier to observe them.

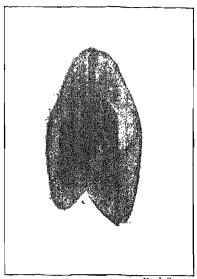
The paramecium has a groove on one surface of its body which leads down to a mouth and gullet. Along the groove and around the mouth are cilia, which beat food particles (principally bacteria) and also water down into the gullet. At the bottom of the gullet the water with the food particles in it collects in little clear droplets that are called *food vacuoles*. These are swept about and scattered all through the animal's body by movements of the cytoplasm. They have the appearance of little bubbles, or clear spaces, in the cytoplasm. Enzymes that digest the food are secreted into the liquid of the food vacuoles.

Toward either end of the body is a large contractile vacuole. These vacuoles collect the wastes of the body and expel them. When at rest a vacuole looks like a drop of water, but from ten to twenty times a minute a sudden change takes place. The cytoplasm about the vacuole contracts and squeezes it and the liquid of the vacuole is shot out in arms through the protoplasm. Some of the liquid passes through the cell membrane to the outside and is discharged from the body. After a contraction the liquid within the organism again collects to form a round drop.

Reproduction in Paramecium. Like Pleurococcus, Paramecium multiplies by dividing. The process requires from 30 minutes to 2 hours and the daughter paramecia grow rapidly. It has been estimated that a single paramecium could increase to 268 millions in one month. As you examine these little animals you may find some that are being pinched in two as they swim about. This is asexual reproduction — multiplication by simple division of the cell.

Reproduction takes place by a sexual process also. Two paramecia may conjugate. They come together and the walls between them disappear. The nucleus in each paramecium divides, making two nuclei in each, and from each animal one nucleus passes over into the other. Then the two animals separate. Each has received a nucleus from the other. In each one the new nucleus that has been received by exchange unites with the one that has remained in place. After the process the proto-





Hugh Spencer

Multiplication of Paramecium by division. Under your microscope you can doubtless observe these little animals swimming about while the dividing process is going on.

Conjugation of two paramecia (right). The cell walls between them break down and they exchange nuclei.

plasm is reinvigorated. Growth and division go on at a more rapid pace.

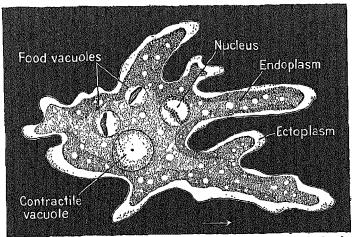
This, of course, is sexual reproduction and even these simple little animals show what may be regarded as sex differentiation. Some individuals will not conjugate with each other but will conjugate at once if placed with a different animal. The descendants that are produced by asexual multiplication inherit the conjugating qualities of the parent organism. It is possible, therefore, to produce a line, the members of which will not conjugate with each other, by placing a single paramecium in a culture by itself and allowing it to multiply.

The Ameba. Another interesting one-celled animal is Ameba. It is simpler than Paramecium and most species are smaller. Amebas are not often found in hay infusions, but sometimes they are present in the material in the bottom of a

fish aquarium. If a bunch of pondweeds is covered with water in a shallow dish, a brown scum will rise to the surface and often after a few days amebas can be found in this.

An ameba has no cell wall about it; it is simply a little naked piece of protoplasm. It moves by a slow creeping movement as a drop of thickish liquid might flow along. A lobe of the cytoplasm moves out ahead or to the side, as perhaps you have seen an arm flow out from a small pool of water on a dusty floor. Then the back part of the protoplasm flows into the lobe. Each lobe is called a *pseudopodium* (sū'do-pō'dǐ-um), or false foot, and an ameba may be thrusting out a number of these at one time. The animal has no fixed shape but constantly varies its form as it moves about.

Within the ameba we find a nucleus, food vacuoles, and a contracting vacuole. There is no mouth; yet the animal has a way of eating. If an ameba comes upon anything that it can use as food the protoplasm flows around the food particle and thus takes it inside itself. If you can watch an ameba under the microscope you will probably be able to see it engulfing bacteria or perhaps one-celled algae. After the food is taken in, it is

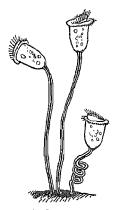


An ameba. It is a speck of soft protoplasm that moves slowly along with a flowing movement. It engulfs any food particles that it meets.

digested. The ameba very easily disposes of any indigestible solid materials by flowing on and leaving them behind.

When hard times come for an ameba (as when the pool in which it lives dries up) it builds a heavy wall about itself and *encysts*. In the encysted state the ameba can endure drying and can live without nourishment for a long time. The ameba multiplies by simple cell division.

Vorticella. Another fresh-water protozoön that you will probably find is *Vorticella*. You will recognize it by the long stalk by which the animal is attached. There is a mouth at the



Vorticella, an interesting form commonly found in protozoon cultures.

end opposite the stalk, with a row of cilia about it which beat small food particles down into the mouth. If the water is yielding no food the stalk may suddenly contract into a short spiral, pulling the animal down to where the stalk is attached. Then the stalk will relax and the animal will float out in a new direction where food may be more plentiful. Or a vorticella (plural, vorticellae) may break loose from its stalk, swim to a new place, attach itself, and grow a new stalk.

The stalk is a part of the cytoplasm specialized for contraction and it may be used not only in helping the animal to find food but for taking it out of danger. If a para-

mecium comes swimming along and bumps into a vorticella, the stalk contracts and snaps the animal down to its point of attachment. Here it lies quiet until the disturbance is past. If the vorticella is in danger because of a carnivorous protozoön or a larger animal that is attempting to feed on it, the stalk will contract and pull the vorticella away. It is interesting to see how suddenly the stalk jerks the little animal down. You can make it contract by tapping on the microscope slide with a pencil.

Reproduction in Vorticella. Vorticella multiplies by cell division. The bell splits lengthwise and one half frees itself from the stalk and swims away. Soon it settles down and grows

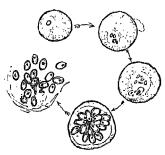
a new stalk and a new animal has been formed. This multiplication by cell division is asexual reproduction.

As in Paramecium, there is a sexual process also. Sometimes the vorticella divides unequally and the smaller portion of it swims away. Then this smaller part instead of settling down and growing a stalk unites with another vorticella. It swims up to a full-sized animal and clings to it. The walls between the cells break down and the protoplasms of the two cells fuse. The smaller cell is regarded as a male gamete and the full-sized animal that united with it is considered to be the female gamete, or egg cell. The process is a sexual one, for in it there is a union of cells.

The malaria germ. The members of one class of protozoa, the Sporozoa, are all parasites and they all produce asexual

spores. The malaria germ belongs to this group and its methods of reproduction remind us of the reproductive processes of some of the fungi and the green algae.

The malaria germ lives like a little ameba in a red blood corpuscle. It grows until it fills the corpuscle and then it divides into a number of asexual spores. The corpuscle breaks to pieces and the spores are set free in the blood. Each one is a little piece of soft protoplasm with a nucleus. Each settles on a fresh corpuscle and repeats the growth cycle. In this



The malaria germ in a red blood corpuscle. The germ grows until it fills the corpuscle. Then it divides into a number of spores, each of which settles on a new corpuscle and repeats the cycle.

way the germs are transferred to new corpuscles and a victim may be kept infected for months or years.

The little malaria animals have a sexual method of reproduction also. In some blood corpuscles they grow somewhat larger than usual and fail to divide into asexual spores. These germs die if the corpuscles containing them stay in the human body; but if the right kind of mosquito, *Anopheles* (a-nŏf'e-lēz), bites the person and draws the corpuscles out, the germs develop into

gametes in the juice of the mosquito's stomach. Some of them round up into eggs. Others divide into four or eight swimming sperms. A sperm unites with an egg—fertilizes it—and the egg, lying free in the mosquito's stomach, is ready for further growth.

Gradually the fertilized egg changes into an elongated wriggling little object that bores into the mosquito's stomach wall. It comes to rest between the layers of the stomach wall and there

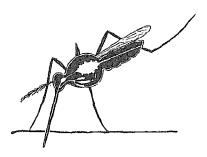


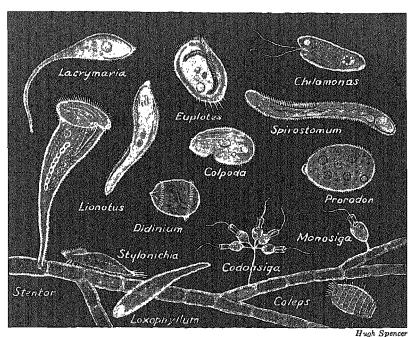
Diagram of a mosquito's body and of the development of the malaria germ in it. The mosquito gets malaria from man and man gets it from the mosquito.

begins to grow. It increases in size and makes a kind of cyst, or sac. The nucleus divides and divides until finally the whole inside of the cyst is made up of slender little cells, each of which is an asexual spore. The wall of a mosquito's stomach may be dotted over with these little bag-like cysts and in them multitudes of asexual spores are produced. The spores go all through the mosquito's body

and reach the salivary glands. Then when the mosquito bites a person it injects the malaria spores into his blood. There the spores attach themselves to blood corpuscles and set up growth and the person is infected with malaria. Man gets the disease from the mosquito and the mosquito gets it from man.

It will thus be seen that in the life cycle of the malaria germ there are two sets of asexual spores and also gametes. By the first set of spores the germ is multiplied in the blood of its human host. By the gametes it gets into and infects the mosquito host. By the second set of spores it reaches the salivary glands of the mosquito and the blood of another human host. Its reproductive methods are adapted both to multiply it and to enable it to make the transfer from host to host.

Other common protozoa. Some of the other kinds of protozoa that you may find as you examine materials under your



Some common kinds of protozoa. This illustration may help you to identify some of the kinds that you find.

microscope are shown above. The members of the phylum are spoken of as the one-celled animals, but in a few species an individual may consist of a little group of cells. In these groups the cells are very loosely connected and each one practically leads its own life. There is no differentiation of cells for special kinds of work as we find in higher forms.

One species that you may be especially interested in if you find it is *Didinium* (dī-dǐn'ĭ-um), which can be recognized by its long sucking snout. It is carnivorous and at one meal it can eat a paramecium ten times as big as itself. After the feast its body is a mere covering stretched around the food. Yet in an hour or two the meal is digested and the little animal is ready to eat again; it may devour eight or ten paramecia in a day. Seemingly plenty of food is required to carry on life in the protozoan way. Another carnivorous form is *Lionotus*, shown above.

Other protozoan forms that may be of particular interest to you if you happen to find them are the large trumpet-shaped Stentor and Monosiga and Codonsiga. The disk at the top of Stentor is covered with cilia which beat bacteria, small protozoa, food, and other materials down into a gullet. Monosiga and the colonial Codonsiga have a long flagellum at the top of the cell. Rising in a cup-shaped way about the base of the flagellum is a collar of soft protoplasm. The flagellum whips food particles down into the collar, where they are engulfed.

The Protozoa are the simplest and most primitive type of animal life. Instead of being composed of many cells with groups of cells differentiated for special tasks the whole animal is made of a single cell. In some of them, like Paramecium, the cell is very large and different parts of it are specialized for different tasks; but their very plan of organization condemns the Protozoa to smallness and insignificance. Yet they are a highly successful phylum. There is an astounding variety of forms among them. They have adapted themselves to living everywhere in earth and water and a whole group of them are parasitic on higher forms.

PROBLEM TWO

What Small Organisms Are There That Are Difficult to Classify as Either Plants or Animals?

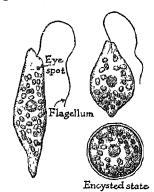
Which were first on the earth, plants or animals? It would seem that plants must have existed first, for animals could not have lived without plants to make food for them. Possibly, however, when protoplasm first appeared on the earth it was not differentiated into plant and animal kinds. It may have been that before either plants or animals existed there were little creatures that were a kind of combined plant and animal. In this problem we shall study several simple forms that are difficult to classify as either animals or plants.

THE PLANT-ANIMALS

It is easy for us to conceive of a one-celled combination plantanimal — an organism somewhat like a green paramecium that

could swim about and yet had chlorophyll and could make its own food. We do not know whether you would have found such organisms in the mud puddles when life was young on the earth, but there are plenty of them today. One of the commonest of them is Euglena viridis.

Euglena. Sometimes in a barnyard puddle (also sometimes in an aquarium) the water will become a soupy green. Put some of this water under a microscope and you will probably find it



Euglena in the free and the encysted states.

filled with little pear-shaped green bodies that are darting actively about. These are Euglenas (u-glē'nas). At the larger end Euglena has a *flagellum* (fla-jĕl'um) like a single long cilium that lashes the water and draws the body forward. Close below the flagellum is a mouth (in some species probably never used) and

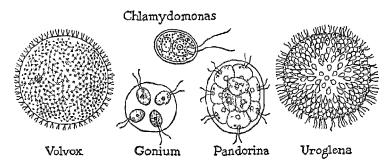
toward the mouth end is a red "eye spot." The cell wall, like the cell walls of animals, is albuminous and the little organism squirms and turns easily about. The pigment that gives the green color is chlorophyll.

Getting through hard times. The ditches and puddles in which Euglena lives frequently dry up. When this happens the little organism builds a thick wall about itself and goes into the encysted condition. In this state it rests, dormant and unharmed by drying. Then when rain comes the cyst breaks and the free, active life is resumed. Euglena goes through these changes rapidly. Its life is counted by hours and days, not by months and years. If you want to find organisms like Euglena in the active stage you must look for them at the right times.

Reproduction. Euglena reproduces asexually by longitudinal division—it simply splits from end to end. One half keeps the old flagellum and the other half develops a new one. Often too there is fission while the organism is encysted. Usually in a cyst the protoplasm divides into two parts, but each of these parts may again divide, making four. Occasionally division goes on until as many as thirty-two of the little organisms escape from a single cyst. Each has its flagellum. Each is a young and small Euglena that will grow to full size.

Relatives of Euglena. The common species of Euglena (Euglena viridis) has many relatives. Some have chlorophyll and are green. Some have brown or red pigment in addition to the chlorophyll. Some are colorless and live by absorbing brokendown molecules of decaying organic matter from the liquid in which they are bathed, as small animals do. One species of Euglena is a parasite in the intestine of the tadpole. One slender kind (Euglena gracilis) is bright green in color, but if it is put in the dark in a nutrient solution it loses its chlorophyll, absorbs food from the water, and goes on with its life.

In more advanced textbooks of zoölogy you will find descriptions of other free-swimming green organisms (as *Chlamydomonas, Uroglena, Pandorina, Volvox*). Decide for yourself whether you will call these and the Euglenas animals or plants. It is a



A group of free-swimming green organisms. Decide for yourself whether you will think of such forms as animals or as plants.

help in biological thinking to know that such living forms exist and if you find them under your microscope you will surely be interested in knowing what they are.

THE SLIME MOLDS

The slime molds are jelly-like beings that live in dark and damp places. They are found in woods, where they creep under leaves and logs. They are sometimes found about piles of old boards. One of them is a mass of protoplasm with hundreds and thousands of nuclei in it but with no cell walls dividing it into compartments. Some of the masses are no bigger than a dime or a quarter; others are as large as your open hand. Many are a bright orange in color.

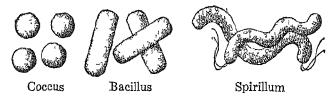
Nutrition of slime molds. The mass of naked protoplasm that makes up the body of a slime mold goes flowing or creeping slowly along like a giant ameba. If it meets anything that it can use for food it flows about it and engulfs it. Inside the protoplasmic mass the food is digested; any indigestible material is disposed of by the organism's moving on and leaving it behind. In the manner of getting their food the slime molds are like animals, for they have no chlorophyll and live on food that has already been prepared. Recently an investigator has learned how to feed slime molds and keep them growing in the laboratory by sprinkling oatmeal over them. Possibly you may wish to raise some of them and observe them for yourself.

Reproduction. In its reproduction a slime mold is quite like a fungus. At a certain stage in its life or when external conditions cause it to do so it leaves the darkness and damp and climbs up on a log, stump, or other object. Then a multitude of sporangia form and the protoplasm inside each of these is cut up by cell walls into tiny one-celled spores. Each spore has a single nucleus. Each is enclosed in a cellulose wall. The spores blow about and those that fall in favorable locations germinate and produce new organisms. In every way these spores are like the spores of such fungi as the bread mold. The slime molds are therefore usually classed as fungi or as relatives of the fungus group.

THE BACTERIA

Bacteria are one-celled colorless little specks of protoplasm so small and so transparent that in examining materials with a microscope it is easy to overlook them. They live in water and in the earth and many of them are parasites of higher plants and animals. They get their food by absorbing it from the materials in which they grow. Many of the bacteria have cilia and swim actively. There are hundreds of species of them and an endless number of varieties. Under a microscope that magnifies a thousand diameters they appear about as large as periods and commas in ordinary print.

According to their shapes bacteria are classified in three groups, the *cocci* (kŏk'sī), the *bacilli*, and the *spirilla*. A coccus (kŏk'us) is shaped like a ball; a bacillus is rod-shaped; a spirillum is spiral.

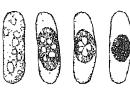


The three shapes of bacteria. The shapes of bacteria have nothing to do with their disease-producing power or other characteristics, but the differences in form are used in classifying them and in identifying particular kinds.

Characteristics and culture. In a bacterium the nuclear material is scattered in granules through the cytoplasm, as it is in the blue-green algae. The wall about the cell is made of albumen, as in animals. The bacteria reproduce only by simple cell division and their powers of growth and multiplication are very great. When food fails or when they dry up many of them

produce spores. A spore is formed by the protoplasm gathering itself into a hard little ball which contains little water and has great resistance to drying and heat. Under favorable conditions a spore germinates and produces the active growing form. Only a few kinds of the diseaseproducing bacteria form spores.

In laboratories bacteria are cultured by placing them in media that supply



Formation of a bacterial spore. The spores of many kinds of bacteria can endure boiling for hours and drying for years.

them with the materials they need for growth. Milk, beef broth, or vegetable broth may be used. Minerals and digested proteins ("peptones") are usually added to the cultures. Often gelatin or agar ("plant gelatin") is used to give a solid culture medium. The making of media suitable for various kinds of bacteria and the distinguishing of different kinds is a great science in itself.

Relationships of bacteria. The action of certain bacteria in water causes iron to be deposited on the bottoms of some bogs and pools. That is the only way in which we know that free iron is deposited. Consequently the presence of veins of iron in ancient rocks leads scientists to infer that bacteria must have existed before those rocks were formed and that they are very old inhabitants of the earth. They are usually classed with the fungi and may be looked on as tiny plants that have lost their chlorophyll. Some of them tend to grow in filaments and with their scattered nuclei they might be regarded as relatives of the blue-green algae. Yet some of them can get energy by breaking up sulfur and iron compounds and others can use as food some of the gases and compounds of petroleum, which other living things cannot use. Also some bacteria have a purple pigment with

which they can build food compounds much as the green plants build them with chlorophyll. In a later unit the place of the bacteria in the general nutritional scheme will be discussed. It is evident that they are very simple little beings that are hard to classify as either animals or plants.

FILTERABLE VIRUSES

There are many diseases of both plants and animals that are caused by *filterable viruses* (vī'rus-es). Measles, smallpox, influenza, tick fever, encephalitis (sleeping sickness), and the common cold are virus diseases of human beings. Yellows and mosaic diseases are virus diseases of plants. The viruses are called "filterable" because they pass through fine porcelain filters that will stop bacteria. They are so small that they cannot be seen with a microscope.

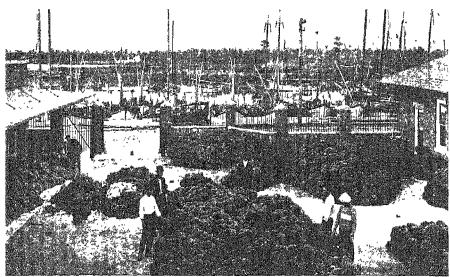
Nature of filterable viruses. Whether the viruses are "firstlings of life," or whether they are non-living substances that have the power of growth and so can reproduce themselves, we do not yet know. They seem to be a connecting link between the living and the non-living worlds.

Scientists have found ways of isolating some of the filterable viruses, and the one that causes the mosaic disease of tobacco has been carefully studied. When this has been separated from the materials of the leaf and stem of the plant it is found that the virus is a protein. Its molecule is of giant size, but it will crystallize as other proteins do. It seems not to be alive. Yet if a little of it is put into a leaf of a tobacco plant it multiplies and causes disease in the plant. It builds the protein of the tobacco plant into protein molecules of its own kind. Forty per cent of the protein in a badly diseased plant may be virus protein.

A THIRD KINGDOM

In some of the more advanced books on biology living things are classified into three kingdoms instead of two. Forms like the Euglenas, the slime molds, the bacteria, and the blue-green algae are not classed as either plants or animals but are placed in a third kingdom which is called the Protista, or "first beings." The idea is that the first beings were neither plants nor animals; that they were forerunners of the plants and animals; and that the plant and animal lines have developed as two separate off-shoots from the first living forms.

It seems reasonable to believe that the first living things, whatever they were like, were able to make their own food and that dependent forms have developed from them. The fungi seem like algae that have lost their chlorophyll. Bacteria might easily be thought of as tiny colorless blue-green algae. The colorless Euglenas indicate how a protozoön might arise from a green one-celled form. We shall not try to trace relationships among the lowly beings. It is enough to note that among the forms still living on the earth there are some that seem to be firmly set in neither the plant nor the animal way.



Tarpon Springs Chamber of Commirce

Sponges on the pier at Tarpon Springs, Florida. The sponges are gathered by divers from the bottom of the Gulf.

PROBLEM THREE

What Is the Plan of Organization and Mode of Life of the Sponges?

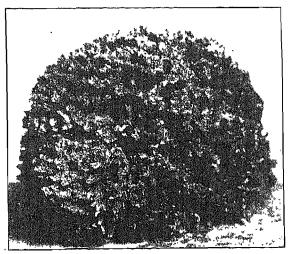
One way for cells to live is to live alone. The other way is for them to live in colonies. In all the animals except the Protozoa the cells live in colonies. A minnow swimming in a pool is a group of cells darting through the water. A spider running across the floor is a cell collection hurrying for shelter. A butterfly flitting among the flowers is a cell colony in search of food. Different types of multicellular animals represent different ways of organizing the tissues and organs so that the cells can live together in a coöperative way.

Sponges are multicellular animals that have a plan of body organization very different from that of all other animal forms. In them there is little differentiation of the cells into tissues. They lack all the organs and sets of organs animals of any size ordinarily have. Yet in a sponge we find a great group of cells living together and sharing in a common life.

Varieties of sponges. There are about three thousand known species of sponges and all of them live in the water. Most of them are marine, but there are a few small fresh-water species. They grow attached like plants and the larger ones have no particular shape or form as most animals have. Rather, like one of the higher plants, they branch and grow as they have room. Because they are fastened in place and because of their lack of definite form the sponges were until comparatively recently classed as plants.

Some of the sponges are as small as pinheads and the largest are 5 feet in diameter. The commonest fresh-water one (Spongilla, page 987) appears as a greenish lichen-like growth on logs and rocks in lakes and streams. The green color is owing to the presence of algae that live within the sponge. Only a few kinds of marine sponges are of commercial value. Sometimes individuals of a choice variety are cut into pieces and the pieces planted for a new crop.

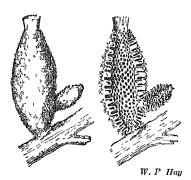
The sponge plan. As we have stated, there is in the sponges little specializing of the cells. A sponge has no muscles, no nerves, no gland cells. In it we find no mouth or digestive



Skeleton of a sponge. What we call a sponge and use in washing automobiles is the skeleton of the animal after the living part has been removed.

tract, no respiratory or circulatory system. Like the cells of our supporting tissues (bone, cartilage, connective tissue), the sponge cells are builders. They secrete a skeleton to which the soft, living tissue clings in a thin layer. The sponge plan is to build a great supporting framework over which the living cells spread out in a layer so thin that each cell can get food and oxygen from the water for itself.

Sponge skeleton. In some kinds of sponges the skeleton is made of calcium carbonate. In others it is composed of tiny



A simple sponge and its reproduction by budding. At the right is a section of the sponge to show its structure.

needle-like spikes of silica. In still other kinds the skeleton consists of fibers of spongin, a nitrogen-containing substance chemically allied to silk. The "sponge" with which you wash a car is made of spongin. It is the skeleton of the animal. Gathering sponges for their skeletons is a minor industry in some places.

In our own country there is a sponge fishery at Tarpon Springs, near Tampa, on the west coast of Florida. The sponges that are

found near Tarpon Springs grow on the bottom of the gulf where there are no cold currents and usually where the water is about 50 feet deep. They are harvested by divers, who cut off the sponges at the base. After being allowed to die and to decay for a day or two the slimy layer of soft tissue is washed from the sponge skeleton. Then the "sponges" are sent to the packing houses to be trimmed, sorted, and perhaps bleached, before they are ready to be sold.

Structure of a sponge. A very simple little sponge is shown above. The body wall is pierced by a multitude of tiny canals, or pores. At the free end there is a large opening called the osculum. This looks like the mouth of the animal, but it serves a very different purpose from a mouth, for water flows

out of the sponge through it. Like many other stationary water animals the sponges set up currents in the water, that bring their food and oxygen to them.

The small canals, or pores, through the wall of a sponge are lined by soft, active cells, each of which bears a flagellum. The flagella work together to beat the water inward through all the little pores into the central hollow in the sponge. As the water passes in, the cells lining the pores seize and engulf any bacteria or other food material in it. The living cells also absorb molecules from decaying organic matter in the water. The water is fanned by the flagella in through the pores and passes out through the osculum. From the water that flows through a sponge the cells obtain their food and also their oxygen supply. Into the water the wastes of the cells (carbon dioxide, protein wastes) are given off.

A large sponge is too complicated in structure to be described here. It starts simple and grows by continued branching. The large central cavity has many side branches into which a multitude of pores lead from the outside. Where sponges grow close together a number of them may fuse and grow as a kind of compound animal in one mass. They may grow so completely around shells and masses of coral that these are enclosed within the sponge. In the openings of large sponges shrimps and small fishes may find a home.

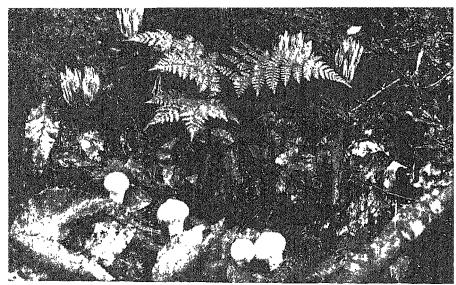
A specialized type of cell. After the food that is taken in by the lining cells of the canals is digested some solid refuse remains. This solid waste material is disposed of in a surprising way. It is engulfed (taken up) by active ameboid cells that live down in the tissue of the sponge and are somewhat like our own white corpuscles. After loading up with refuse, one of these cells crawls out between the other cells into the water and dies.

An ameba takes up materials it can use for food and rejects wastes. It goes away from that which harms it. The ameboid sponge cell takes up refuse particles that are useless to it and after — not before — it has accumulated a load of these it goes out into the water to its doom. Something in the sponge organi-

zation causes these cells to sacrifice themselves for the welfare of the group. Our own white corpuscles sacrifice themselves with equal valor when our tissues are invaded by germs (page 595).

Reproduction in sponges. Sponges multiply by budding. A bud may grow into a new animal beside the parent one or it may separate and locate in a new place. Sponges multiply also by gemmules. These are little bunches of cells that have a wall formed about them and are then set free. Fresh-water species die in the fall and the gemmules, like seeds or resistant eggs or spores, carry the organism over until spring. Sexual reproduction also is found through the sponge groups. Eggs and sperms develop in the body wall and are discharged into the water. The fertilized egg develops into a little creature with cilia that swims for a time and then settles down and grows into a sponge.

Some species of sponges grow to a considerable size, but there is no differentiation into organs. Each part of the body is a monotonous repetition of other parts. If a sponge is cut into pieces each part will grow into a complete new sponge. A branch of one can easily be grafted on another. By adopting the multicellular plan and building a skeleton on which the living tissue can be spread out the sponges found a way to increase their size, but they have failed in the cell specialization and tissue differentiation that is required for active life.



Horace Mckarland

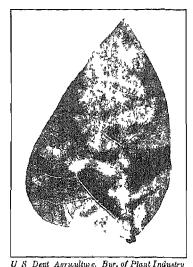
Puffballs and coral fungi in a woodland. They live as saprophytes in the vegetable matter in the forest floor.

PROBLEM FOUR

How Do the Fungi Meet Their Life Problems?

The fungi are much like the algae in structure, but they have no chlorophyll. They cannot, therefore, build their own carbohydrates as the algae and other green plants do. Like ourselves they must have their sugar already built up for them or must get compounds that they can digest and break down into sugar. This makes necessary a mode of life entirely different from that followed by the green plants.

More than forty thousand species of fungi are known. Molds, mildews, rusts, smuts, mushrooms, puffballs, and the bracket fungi that we see on trees and logs are all members of the group. Yeasts often are classed as fungi, and bacteria are probably close relatives of the fungus group. Among the fungi as in the sponges there is little specialization of cells. Even the larger ones like the mushrooms and bracket fungi are made up of a tangle of simple filaments. We include the fungi with the simpler organisms because among them there is little differentiation of the cells.



Mildew on the leaf of a soy bean. It lives as a parasite, feeding on the living cells of the leaf.

Fungus ways of life. Many fungi live on dead organic matter. These are saprophytes (Greek sapros, decayed, + phyton, plant). They grow in rich earth or in wood, or like the molds found on bread, cheese, and bacon they grow on the surface of some material and send into it little root-like structures that draw out the nourishment. Many of these fungi have enzymes that digest wood, cellulose, and other substances that we cannot digest. They use these materials as a source of carbohydrate. A mushroom growing in the earth digests and

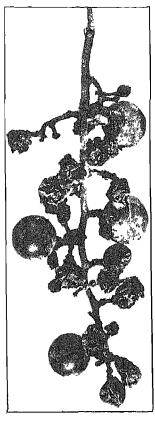
uses for its sugar supply the fibrous materials of plant remains that it finds in the soil. A bracket fungus growing on a dead log digests and uses the wood.

Many fungi are *parasites*. They grow in or on living things and take their nourishment from them. The mildews, rots, rusts, smuts, and wilts, that cause so many plant diseases, are of the parasitic type. There are hundreds of small fungi that get their living as parasites. An animal or a plant on which a parasite lives is called the *host*.

The molds. You have already studied the bread mold (page 124). Many other mold species, most of them much finer than bread mold, are very common. On leather, cloth, bacon, cheese, or damp cellar walls and floors you will find spots of dark green or bluish mold. Most molds are inoffensive little plants merely trying to pick up enough food to get along. A couple of them that grow in Camembert and Roquefort cheese even pay for their food by giving characteristic and greatly appreciated flavors to the cheese.

There are, however, a few molds (or perhaps we should consider them relatives of the molds) that have turned parasitic and are not so harmless. One of these, growing in the skin, causes ringworm. Another is responsible for "athlete's foot," and still another for a tropical skin infection called "dhobie itch." An occasional supposed case of human tuberculosis proves to be an infection of the lungs with a fine fungus. One kind of mange in domestic animals is caused by a fungus. And brooder pneumonia in baby chicks can start from fungus spores that were on the straw. brown rot of fruits is a member of the mold tribe that has become parasitic on plants. Examine with a microscope a little material from a rotting apple, peach, or sweet cherry and you will find it filled with fungus threads.

The mildews. The mildews live on plants, usually in or on the leaves. Examine, especially in late summer or autumn, the leaves of clover, lilac,



The photograph above shows all that remained of a cluster of grapes after it had been attacked by black rot.

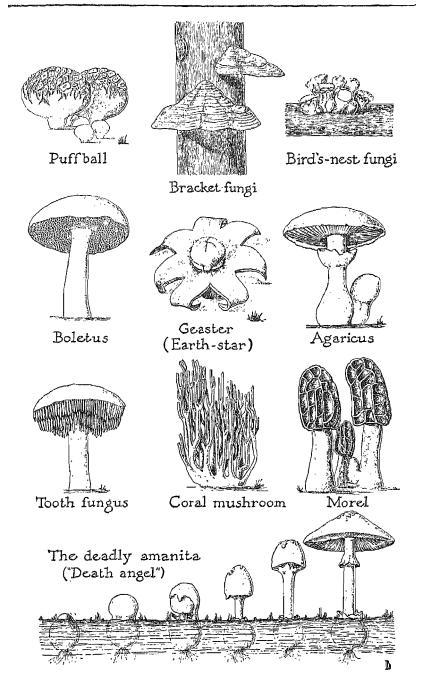
rose, grape, cocklebur, dandelion, or other plants. Often you will find the leaves whitish in spots. A fine fungus is causing the whiteness. Some of the mildews (as on the lilac) grow on the surface of the leaf and get their nourishment through filaments that, like little rootlets, grow down among the interior cells. Other mildews, as on the potato, grow inside the leaf. Those that grow inside the leaves thrust out through the stomata the filaments that bear the spores.

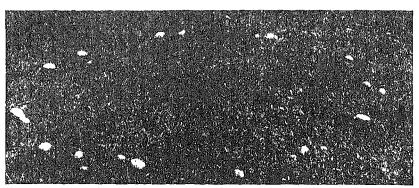
The mildews produce a multitude of fine spores that spread the diseases by being blown about. The spores fall on the leaves of

plants not yet infected and germinate in droplets of dew or rain. The diseases they cause are very naturally worse in damp seasons. The way to prevent them is to spray the host plants with a fungicide (usually a spray containing a sulfur or a copper compound is used) or to dust with sulfur. Usually the fungicides are combined with sprays against insects. Against the fungi that grow within the leaf it is especially important that preventive measures be used, for after the leaf is infected the parasite cannot be reached.

Other parasitic fungi. There are many other kinds of parasitic fungi. There is a great group of rusts and smuts that attack especially the grasses and grains. There are wilts that penetrate the seedlings of cotton, melons, and other plants and grow so abundantly in the water vessels as to plug them and cause the plants to wilt. There are "damping off" fungi that attack the tender seedlings in moist greenhouses and rot them off just above the ground. There are leaf spots on the apple, pear, cherry, and quince, that are caused by minute fungi in the leaves. There are rots of fruits and vegetables for which fungi are responsible.

For years many trained scientists have been studying the life histories of these parasitic fungi and working out methods by which they can be controlled. Each one of the fungi presents its own problems and if you have to deal with a fungus disease your proper procedure is to get instructions prepared by an expert and follow them in detail. It may be necessary to sterilize seed before planting, to kill the spores on it. It may be necessary to clean away and burn old leaves on which fungi pass the winter. be necessary to move a crop to new ground or to spray with a definite material at a special time. Many of the parasitic fungi have two hosts and pass from one to the other as the malaria parasite passes between the mosquito and man. One generation of the fungus that causes the spots on apple leaves lives on the cedar (in "cedar apples") and another fungus alternates between the gooseberry and the white pine. The problems that arise in preventing and treating a plant disease are many and varied and the beginner had best follow the plant doctor's advice.





Nature Magazine

The fairy ring. The mycelium of the mushroom began to grow in the center of the ring and has worked outward. As it advanced it died away in the center, leaving the filaments in the earth as a circle. Consequently, when the mushrooms appear above ground they are in a ring.

The mushrooms. Have you in a pasture seen a "fairy ring," a circle of mushrooms springing up in the sod? The old explanation of the circle was that the fairies had met and danced about in a ring in the moonlight and where their feet touched the earth the mushrooms came up. There is another explanation, less poetic but scientifically more satisfactory.

The main body of a mushroom is in the ground, a great tangle of fine filaments called the *mycelium*. It starts from a spore in one certain spot and grows outward in all directions. As it advances through the soil it exhausts the food on which it lives; consequently after it has grown for a time it dies away in the center and exists as a ring. The filaments grow in the soil and collect food within themselves and from time to time they throw up "mushrooms" to the light and air above. These are the spore-bearing parts of the plants.

On the gills or in the pores on the underside of the mushroom umbrella a multitude of small spores are produced and when these have ripened and have been scattered to the winds the part of the plant above ground dies. The underground part of the mushroom, however, remains alive. It grows on, collects more food, and in time produces another mushroom crop. The mushrooms in a "fairy ring" stand in a circle because they are above the ring of filaments that have been advancing from a common center in the ground.

The puffballs. The story of the puffball is similar to that of the mushroom, except that the part above ground is a ball with spores on the inside. When you step on a dry one millions of spores puff out. Examine under a microscope some of the dust from a puffball and you can see the little spores of which it consists. All the puffballs are non-poisonous; so if you wish to gather fungi for eating you can start your collecting with them. Be certain, however, that you do not mistake for puffballs young mushrooms that are still in their small rounded form.

Bracket fungi. The bracket fungi grow on the sides of trees or logs. The filaments of the fungus make their way through the wood, living on the food material they obtain from this. The

spore-bearing part of the plant — the part that corresponds to the mushroom or puffball — grows out like a shelf on the side of the tree. Some of the bracket fungi damage living trees and some help to cause the decay of timbers that have been cut.

Importance of fungi. Mushrooms are used for food, and yeasts are of service to man, but it is the plant parasites of the

Indian pipe. A flowering plant that has no chlorophyll and like many fungi lives as a saprophyte. It grows in forests and absorbs its nourishment from the vegetable materials in which it grows.



fungus group that are of the greatest concern to us. Their spores are blown and scattered about everywhere and when the farmer or gardener tries to raise his crops these little plants fasten themselves on the larger ones and draw the nourishment from them. The extent of the damage that they cause is unbelievable and the amount of labor expended in spraying, dusting, sterilizing seed, and carrying out other measures for their control is very great. A world without rusts, blights, mildews, and other parasitic fungi would be for the plant grower a vastly different and much happier place.

Origin of the fungi. In a field planted to corn an occasional white plant comes up. Seedlings that have lost their chlorophyll appear among the offspring of many other kinds of plants. These seedlings die as soon as they exhaust the food supply in the seed, but if they could survive we should soon have a very diverse group of non-green plants. The Indian pipe and a few other species of seed plants have found it possible to live on as saprophytic or parasitic forms. The occurrence of these colorless individuals and species among the higher plants suggests that the fungi are descended from alga-like forms that lost their chlorophyll and survived by turning to a saprophytic life (pages 581–582).

Like the bacteria and viruses, the fungi are very changeable. When plant breeders produce a variety of wheat or other grain that is immune to a fungus attack, a mutation is likely to occur in the fungus that will give a strain able to grow on the new grain type. This mutability is doubtless an aid to the fungi in developing adaptations to new ways and conditions of life.

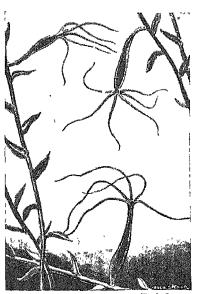
PROBLEM FIVE

What New Plan of Body Organization Does the Hydra Introduce?

Bring in some plants from a pond, stream, or spring and place them in clear water in a glass jar. After all has become quiet you

are likely to find hydras attached to your plants. If you do not find them the first time try again with plants from another source. Better still, let a number of your classmates bring in plants from different locations at the beginning of the search. Hydras are not always easy to find.

A hydra is from ½ to ½ inch in length and has a circle of tentacles or arms at the free end. Stretched out in the water it looks like a piece of thread with the fibers raveled out at the unattached end or like a very delicate star-like flower with a slender corolla or tube. Usually



Hugh Spencer

Hvdra.

the color is whitish. In some kinds it is brown or green. If the animal is disturbed it shortens up into a little ball and pulls in the tentacles until each tentacle looks like a tiny bud on the ball.

Body plan of the hydra. The body of a hydra is hollow, closed at one end, and with a mouth at the other. Its only organs are the tentacles that wrap themselves about small animals or other food and feed them into the mouth. The whole animal is little more than a slender stomach with arms to feed it.

An animal such as a worm, insect, or fish has a head end. It has dorsal (back) and ventral (stomach) sides and a right and left side to the body. The hydra is not built on this plan. It has

oral (mouth) and aboral (away-from-the-mouth) ends and the body is radial. The body is built around the mouth and radiates out from it.

Weapons of the hydra. The hydra captures small animals by first stinging them into subjection with its *nematocysts* (něm'a-to-sĭsts), or "nettle cells." These are studded thickly over the tentacles and also over the outside of the hydra's body. A nettle cell is hollow and is filled with a poisonous liquid in which a thread is coiled. If a paramecium, a water flea, a small worm, or a very young fish or other small animal bumps into a hydra a broadside of the threads is shot out and often the prey is paralyzed or killed. Then the tentacles draw it into the mouth.

Nettle cells once shot are of no further use. They develop from the outer cells of the body and tentacles and the animal must grow new ones for each attack. Have you ever been stung by one of the small jellyfishes ("water nettles") that are sometimes so abundant in the waters of our Atlantic coast? If so, you have firsthand knowledge of the effect of a nettle-cell salute.

How the hydra moves. If the food supply is not good or if other conditions do not suit it a hydra draws itself up and then stretches out in another direction. Sometimes it changes its location and instead of swimming, as we might expect, it walks. It may travel short distances by inching along on its base. To go farther and more rapidly it can move like a measuring worm, bending over and taking hold with its tentacles and then looping its body and drawing the base up to the tentacles. Sometimes it turns one or more complete handsprings on its tentacles, or it may walk on them.



A hydra walking.

All the hydra's movements are supposed to be made by the method of trial and error. It has no brain and is supposed not to plan what it does or to know where it is going. It makes a move and if this does not carry it to a better location it tries again.

How the hydra digests its food. The inner cells that line the hydra's body cavity are of two kinds and the digestion of the food is carried on in two ways. Some of the cells are large, with a flagellum on each of them that extends out into the body cavity. These larger cells are soft and, like an ameba, are able to catch and engulf any tiny food particles that come within their reach. The food

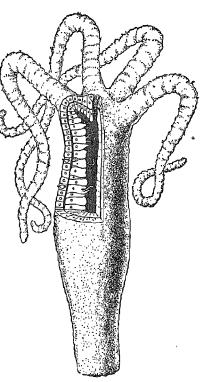


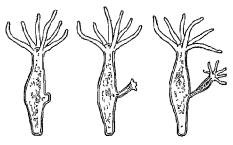
Diagram of the hydra's body.

caught in this way is digested within the cells as in the protozoa and sponges.

Cells of the other type are smaller. They are gland cells that secrete digestive enzymes into the body cavity. Small worms or other organisms that the tentacles catch and feed into the mouth are digested in the body cavity as food is digested in the stomach of a higher animal. The food digested in this way is absorbed and passes by diffusion from one cell to another. Part of it may be passed to the outer cells and stored as oil droplets—the hydra's fat. Digestion and absorption are helped by movements of the body that churn the food about and by currents set up from the beating of the water by the flagella. Any indigestible portions of the food are thrown back out of the mouth.

Reproduction in the hydra. The hydra reproduces by buds. A branch grows out of the parent body and develops a mouth and tentacles. It then breaks loose and starts its independent life.

Eggs and sperms also are produced. A cell in the outer layer of the body wall slips under the others, gathers food, enlarges, and becomes an egg. Other cells divide into small swimming sperms. The sperms are released in the water and swim to the eggs, which



Reproduction of hydra by budding.

are fertilized while still embedded in the parent's body wall. After fertilization the egg begins growth and produces an embryo hydra. This soon goes free in the water, develops tentacles, and becomes a mature hydra. A hydra

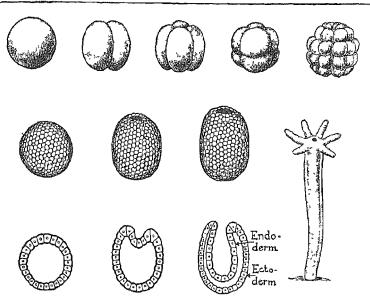
produces both eggs and sperms. It is bisexual — both male and female.

Development of the hydra. When the fertilized hydra egg divides two cells are formed. Then by continued cell division the embryo passes through four-celled, eight-celled, sixteen-celled, and thirty-two-celled stages. In these early stages the embryo is only a small group of cells loosely held together.

Then as the ball of cells increases in size it becomes hollow. A cavity filled with liquid appears in the center and the cells arrange themselves in a single layer around it. The arranging of the cells in a hollow ball brings them all to the outside, where they can secure oxygen.

Next, visible differentiation of the cells begins to take place. On one side of the hollow ball the cells become larger and longer. Then the wall on the side where the larger cells are located is folded in somewhat as one side of a hollow rubber ball might be pushed in with the point of a finger. This gives the embryo the shape of a little cup with the folded-in cells as a lining for the cup. The wall of the cup, as the illustration shows, is made of two cell layers. The outer layer is called the *ectoderm*. The inner layer is called the *endoderm*.

In the next stage of development the cup grows deeper and

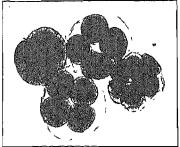


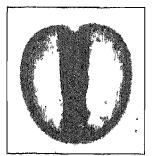
Development of the hydra. A fold down into a hollow ball of cells forms the cavity into which the food is taken. Compare the layers in the body with the drawing on page 303.

deeper until it becomes the slender hollow hydra body. The tentacles grow out as buds from the rim of the cup. Thus there is produced the mature animal. It has a hollow in its body into which it can take food and it has organs to catch the food and feed it into this body cavity. No kidneys or gills develop. The tentacles and body walls are thin and the cell wastes are given off directly into the water and oxygen is absorbed from it.

In the adult hydra there is in addition to the endoderm and ectoderm a thin middle layer of sticky material called the *mesoglea*. This is not composed of cells but of material secreted by the cells. The tentacles are made up of an inner core of endoderm covered with a layer of ectoderm.

Cell differentiation and body organization in the hydra. The hydra is a simple animal, but in it there is a marked differentiation of the cells. There are reproductive cells that provide for the production of another generation. There is a differentiation of the body cells to carry on the activities necessary





Hugh Spencer

Roy M Allen

At the left are early stages in the development of starfish eggs photographed through a microscope; at the right, a section through the embryo of a sea urchin after the endoderm had been folded in. The larger animals in their development go through the same stages as hydra.

for the animal's own life. The hydra is an organism and not a mere collection of cells.

In the ectoderm some of the cells turn into the little stinging weapons we have described. Some have their bases extended as fibers along the sticky middle layer and these are able to contract and serve as primitive muscle cells. There are also nerve cells that form a network in the body wall and are especially abundant near the base and mouth. The endoderm cells are concerned more with the food. They are differentiated into the two types we have described.

The sponges have one plan for having their cells live together in colonies. The hydra has a very different plan; its cells are differentiated into many kinds that carry on the different activities necessary for their common life. In the hydra, too, we find a considerable degree of body organization. Its muscular and nervous systems are connected and work together. The tentacles get the food and the endodermal cells digest it. In the hydra there is worked out in a simple way the plan of making a mass of cells into an organism by differentiating the tissues and organs and governing them through a nervous system. All the higher animals follow the hydra in the adoption of this plan. Look over again the drawings on pages 108 and 132–133 and make sure that you understand the idea of cell differentiation and how cells of

different kinds are developed. As you study plants and animals, learn what you can about the cells of which the different tissues are composed.

The multicellular organisms, because of the fact that their cells live in colonies, have additional problems that the one-celled forms do not face. Food and oxygen must be secured for the whole cell group and distributed through the body. Cell wastes must be collected and excreted. Various activities and chemical processes must be carried on to make possible the communal life of the cell colony. In all the multicellular animal groups except the sponges, these problems are solved by a differentiation of the cells. Special tissues and organs are developed for particular kinds of work and the body is organized so that its parts work together as one whole. The unit is the cell colony and not the single cell.

A GREAT INVENTION AND A PIONEER OBSERVER



Anton van Leeuwenhoek (1632–1723). He was one of the first to use the microscope in the study of small life forms.

Great advances in science often follow the invention of new instruments and nearly all the facts presented in this unit have been gathered by the use of the microscope. Before the microscope was invented and used in biological study men did not even know of the existence of protozoa and bacteria. They knew nothing of spores and gametes and had no understanding of parasitic plant and animal diseases and how they are spread. It was the microscope that revealed the existence of beings so minute

that they are invisible to the unaided eye and of the cell units which make up the higher forms.

The first to apply the microscope to biological studies was Anton van Leeuwenhoek (vän lā'věn-hook), a Dutch grinder of lenses who lived about 250 years ago. He constructed for himself microscopes of better quality than had previously been made and with them examined water from pools and wells, saliva, the tissues of plants and animals, and other materials. He was a pioneer in the observation of small organisms, and drew pictures of the "cavorting beasties" that he saw.

Leeuwenhoek, like a traveler in a strange country, did not understand much of what he saw, but his curiosity was insatiable and he pursued his observations with great diligence. With his microscope he opened for us a great new section of the biological world.

UNIT COMPREHENSION TEST

- A. What are one-celled animals called? On what do they feed? Describe Paramecium. How does it multiply? Describe conjugation in Paramecium. Describe the Ameba and how it moves. What becomes of it when the water in which it lives dries up? Describe Vorticella and its reproductive methods. Tell the life story of the malaria germ. What are some other common kinds of protozoa?
- B. Describe Euglena and tell its life history. What is a slime mold like? How does it reproduce? How do bacteria get their food? What are the three shapes of bacteria? What are the characteristics and relationships of bacteria? Tell something of the filterable viruses. Why has a third kingdom of living things comparable to the plant and animal kingdoms been proposed?
- C. How many known species of sponges are there? Where do they live? Why were they formerly classed as plants? What is the sponge plan of body organization? What range of size is there among the sponges? Of what different materials are the skeletons of sponges composed? Where are there sponge fisheries in our country? * How are the sponge skeletons prepared for sale? What are special features of the sponge structure? Describe the activities of the ameboid cells and the flagellated cells of the sponge. How do sponges reproduce?
- D. How do the fungi differ from green plants in their way of procuring food? How many species of fungi are known? What is the structural plan of a fungus? Define: saprophyte; parasite; host. Describe the molds; the mildews. How do they spread? How are plant diseases caused by mildews prevented? What are some other parasitic fungi? (See also page 590.) Tell something of mushrooms, puffballs, and bracket fungi. How is a fairy ring formed? How many of the fungi shown on page 297 have you seen? Which of the fungi are of most importance to us? How did the fungi probably originate?
- E. Describe a hydra. Define: dorsal; ventral; oral; aboral; radial. What is the body plan of the hydra? How does the hydra capture its food? How does it move from one place to another? How does the hydra digest its food? How is reproduction carried out? Through what stages does the hydra pass in its development from the egg? Contrast the hydra plan of body organization with the sponge plan.

SUGGESTED ACTIVITIES AND APPLICATIONS

- 1. With the low power of the microscope observe paramecia. Look for specimens that are dividing and for conjugating pairs. Make a drawing of an individual, showing as many of the parts shown on page 272 as you can identify.
 - 2. Watch an ameba move. Make a sketch of one.
- 3. Examine Vorticella. Tap on the slide and watch the stem contract. Look for dividing individuals. Make a sketch of the animal.
- 4. Examine stained slides of blood showing malaria germs in the red corpuscles.
- 5. Observe Euglena. Look for individuals in the encysted state. Make a drawing of what you observe.
- 6. Try to identify any other free-swimming green organisms you may observe.
- 7. Examine a small bath sponge that has been cut through the middle. Tear up a small portion of it in a drop of water and observe with a microscope. Note the spongin fibers.

Examine the small sponge called *Grantia* (page 290). Boil a specimen in a strong alkali solution, which will dissolve everything but the skeleton. Under the microscope examine the spicules in a drop of the liquid. Draw a few of the spicules.

- 8. Examine molds from cheese or bacon. Examine a rotten apple or a rotten orange for fungus filaments. Scrape from the surface of a leaf that shows mildew (lilac, cocklebur, grape, dandelion) the fungous material and examine it. Bring in a "cedar apple" (page 590) and place it in a warm moist atmosphere. Examine the jelly-like material of the yellow stringy growth. It is filled with two-celled fungus spores.
 - 9. How could leaf spot disease in apples be prevented?
- 10. Let the class members bring in any kinds of mushrooms, puffballs, and other kinds of larger fungi that they can find.
- 11. Bring in hydras, if they can be found, and watch them. An examination of a tentacle with the low power of the microscope will show the nettle cells.

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UNIT 8 TWO REPRESENTATIVE ANIMAL GROUPS

Worms and arthropods are two highly successful animal types.

"An organism is successful in nature when it lives out its own life and leaves offspring to take its place when it is gone."

E. N. TRANSEAU

Brown Brothers

REPRESENTATIVE INVERTEBRATE TYPES

OUESTION FOR CLASS DISCUSSION

What animal would you say is the highest type of the invertebrates?

THE animals with backbones are called *vertebrates*. All the ones that lack backbones, taken together, are called *invertebrates*. There are many groups of invertebrates and among them we find great diversity of form. Two representative groups of them, the worms and the arthropods, will be studied in this unit. Each of these is an animal type that has proved its worth by survival through long ages and each is a wide present-day success. A common characteristic of the worms and arthropods is that the body has *anterior* (head) and *posterior* (rear) ends, and *dorsal* (upper or back) and *ventral* (lower or front) sides. The body also has *bilateral symmetry*, which means that the right and left sides of the body are similar. This type of body is very different from that of the hydra, which is *radial* and built about a mouth.

The term "worm" is a word of popular and not of scientific usage. It is applied to practically any kind of soft-bodied slender animal that has no skeleton and no limbs. Animals that answer to this description differ so greatly among themselves that biologists place them in three separate phyla, and there are still some forms that do not fit into any of these groups.

In general the worms are burrowers. On land their great home is in the earth, and in the sea most of them live hidden in the mud or sand. Their soft bodies are benefited by protection and they cannot withstand the drying that goes with exposure to the air. There are many worms, however, that do not follow a burrowing life. The arrowworms swim in multitudes in the open sea, and far more than any other groups in the whole animal

kingdom the flatworms and roundworms follow a parasitic existence. Next to the one-celled organisms, these worms are the most common cause of parasitic disease in the higher animal forms. They cause great loss of domestic animals and in the warmer parts of the earth they are a most important cause of human disease.

Phylum Arthropoda includes the Crustacea, the Insecta, the Arachnida (spiders, ticks, mites), and the Myriapoda (millipedes and centipedes). The arthropods have many of the body features of the higher worms, but they are in many ways animals of a higher type than the soft-bodied, limbless worms. They have in addition to the worm structures jointed limbs and jointed skeletons which fit them for active life. The higher arthropods have eyes and ears and either gills or organs for breathing air. They are the most successful of all the animal phyla, for not only have they survived for hundreds of millions of years but they make up a large part of the earth's animal population today. Our studies in this unit will be confined to the land arthropods. The Crustacea, which are the great water group, will be taken up at another time.

Problems in Unit 8

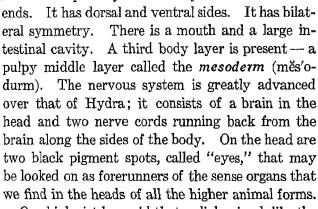
- 1 What plan of body organization is found in Planaria?
- 2 What are the characteristics of the roundworms?
- 3 What advances do we find in the earthworm?
- 4 What are the characteristics and relationships of the arthropods?
- 5 How do we account for the astounding success of the insects?
- 6 What are the life histories of some representative insects?
- 7 What measures are used to keep insects under control?
- 8 What are the characteristics and life habits of the Arachnida?

PROBLEM ONE

What Plan of Body Organization Is Found in Planaria?

Planaria is a simple representative of the flatworm group. It is a thin, soft, flat, dark-colored little animal perhaps a half inch in length. It lives in fresh-water ponds, in shallow parts of lakes, and in quiet streams; you will find it under sticks and stones in water or among vegetation. It hunts actively for the small animals on which it feeds and in doing this it twists and squirms about. It can swim also by movements of the body which send it sailing along through the water and, as in Paramecium, by the power of the cilia with which it is covered.

The planarian body plan. Planaria shows the worm plan worked out in a simple way. The body has head and rear



One biologist has said that radial animals like the hydra, jellyfishes, and starfishes were doomed to a lowly life because they looked in all directions and could not decide in which direction to progress. Planaria very definitely adopted the plan of a head end to the body that in traveling goes before and chooses the way. It is probable that some old-time relative of Planaria had the honor of originating the first brain.

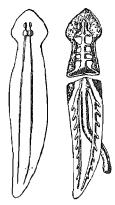


A planarian.

Digestive system of a planarian. Planaria has a mouth on the lower side of the body and a tube-like muscular proboscis that, like the trunk of an elephant, can be thrust out and moved about in search of food. Within the body there is a

large intestine with greatly folded walls into which food is taken for digestion and absorption. There is no anal opening. In the roundworms and the annelids (ăn'e-lĭds) the alimentary canal extends through the body, but in Planaria, as in Hydra, indigestible food refuse is ejected through the mouth. In reality the intestine is much larger and more folded than is shown in the diagrams.

Some flatworms are even smaller and simpler than Planaria. In some the intestine is incomplete, and after food is eaten it is taken in among the soft cells that make up the central part of the body and digested there. In studying one of these simple forms an investigator made an interesting discovery.



Diagrams of the nervous and alimentary systems of a planarian.

The animal eats hydras as a part of its food and after a hydra is digested the nematocysts are left in among the mesodermal cells. The flatworm has the problem of disposing of them. Guess how it does this. It moves them to the outside of its body, arranges them with the points outward, and shoots them at any enemy that troubles it!

Other organs in the planarian body. The planarian has a distinct muscular system which enables it to turn and crawl about, and there are simple organs for the removal of protein wastes. Along each side of the body and opening on the rear of the back is a long tube. Many little branches run off from this tube in among the cells, and at the end of each branch is a cell with a bunch of cilia that beat the liquid down to the tube and through it to the outside. These cells, because of the ceaseless flickering of the cilia, are called "flame cells." They function as kidneys of a very simple type.

Reproduction in planaria. Planaria is bisexual. Each animal, as in Hydra, is both male and female. There are male organs, or *testes* (tes'tes; singular *testis*), that produce sperms, and female organs, or *ovaries*, that produce eggs. Thin-shelled eggs are laid in summer and thick-shelled ones that pass through the winter are produced when autumn comes.

There is asexual reproduction also in unusual ways. A new head and eyes sometimes develop in the middle of the body and then the animal divides in two crosswise. At times also the whole body breaks up into pieces and each piece develops into a new individual. A common experiment in biology courses is to cut a planarian into several pieces and watch each piece develop into a complete animal. The cells are specialized to a degree. Yet if necessary they can multiply and the young cells can differentiate into the various kinds needed to complete the body. We see the same thing happen when a cutting of a plant develops roots and becomes a complete plant. This kind of reproduction in animals is directly comparable to vegetative propagation in plants (page 237).

The easiest way to capture planarians for study is to place a piece of fresh meat in the water where they live. The little dark-colored worms will be found clustered on the meat. There are salt-water forms very similar to the fresh-water ones. If you live by the sea you can probably find these under stones on the beach at low tide or among seaweeds or other sheltering material near the shore.

PROBLEM TWO

What Are the Characteristics of the Roundworms?

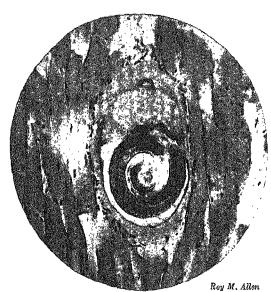
The roundworms are slender and white. They show an advance over the flatworms in that the alimentary canal extends entirely through the body. The most important of them are the nematodes (něm'a-tóds) or threadworms. Nematodes are found by the millions in the soil, especially in warmer regions. They live in the roots of plants and are a great cause of loss in agriculture. They are parasites in animals and man and sometimes rival the bacteria and protozoa as a cause of disease in human beings and domestic Fifteen hundred species have been classified, and the number of individuals is so great that according to one investigator the free-living nematodes in a 10-acre field, if arranged in a single file, would form a procession long enough to reach around the world. In general the roundworms, even the parasitic ones, are more muscular and less degenerate than the members of the flatworm group.

Ascaris. The members of the Ascaris (ăs'ka-rīs) family (eelworms) are typical of the roundworms. Different ones of them are parasitic in horses, dogs, hens, and human beings. They are yellowish white in color and the larger kinds may be as much as 10 or 12 inches long and as thick as a pencil. They live free in the intestine, crawling about and taking in the digested food of the host through their mouths. Reproduction is by eggs and sperms, which are produced by separate individuals. One female may lay as many as 15,000 eggs in a day.

The eggs pass out of the body in the intestinal wastes and develop into small embryo worms. These get thick coatings about them and lie dormant. If they are swallowed by a host they cast off their coverings and bore into the wall of the intestine until they get into a blood vessel. They are then carried to the lungs, where they break out into the air sacs, after which they come up the windpipe and are swallowed again. Then they settle down to their adult life in the intestine.

In pigs that are heavily infested there may be coughing and serious damage to the lungs from the young worms passing through. In some areas human Ascaris infestation is widespread and is a serious health menace. The solution lies in keeping the soil free of pollution by human wastes. Prevention of the infestation is better than treatment after it has taken place.

Other roundworms that cause human disease. Other smaller roundworms that are common as human parasites are hookworms, pinworms, and whipworms. Hookworms were introduced into our country from Africa and notwithstanding all the efforts that have been directed toward their control, infestation with hookworms is widespread in the rural parts of some of our warmer states. The young worms hatch in the soil and get into the human body by boring through the skin, on which they cause "dew sores" or "ground itch." Usually the worms enter the body through the skin of the feet. In the blood stream they travel to the lungs, make their way into the air sacs



A trichina in a piece of muscle. An ounce of lean pork may contain as many as 400,000 of the worms.

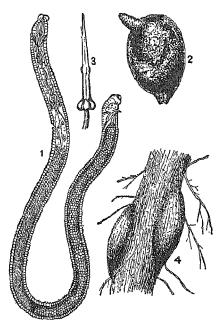
and up the trachea, and are swallowed.

In the intestine they increase in size and live by biting into the lining of the intestinal wall and sucking the blood from the wounds. With a heavy infection children are stunted; adults lack strength for work. The worms in the intestine can be killed with medicines. Their spread can be prevented by keeping the soil free from pollution and by wearing shoes.

The trichina. The trichina (tri-ki'na) is a little roundworm that has

a life history somewhat different from any we have followed. It passes part of its life in muscle tissue and must have two hosts. It uses as hosts for either phase of its life several different animals, among them mice, rats, pigs, and men.

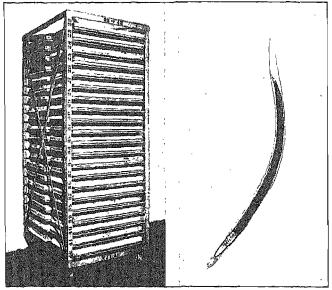
The eggs of the trichina hatch in the intestine, where the young bore through the intestinal wall into the blood. They are carried by the blood stream all through the body and lodge in the muscles. Here, after growing for a time, they go into an encysted state, a coating of calcium carbonate being formed about them. As many as 400,000 of the young worms may be in an ounce of infected pork.



Root-knot worms: 1, the male; 2, the female; 3, the stylet used in penetrating the plant tissue; 4, portion of root injured by these worms—all much enlarged. In some of the roundworms the male and female differ greatly in size.

If meat containing the worms is eaten, the cysts are dissolved, the worms rapidly grow to maturity in the intestine, and eggs in great numbers are produced. These at once hatch, bore through the intestinal wall, reach the muscles, and cause the disease called trichinosis (trĭk'ĭ-nō'sĭs). The symptoms of a severe infection are great soreness of the muscles and fever. Pigs get the worms from rats, and cats get them by eating rats and mice. In man the disease is caused by eating only partially cooked pork. Pork from garbage-fed hogs is especially likely to contain trichinae. Many cases of trichinosis in man are never recognized.

Nematodes in plant roots. The root-knot worms are another great division of the roundworm clan. Four hundred



U. S. Dept. Agriculture

Not all nematodes are injurious to man. At the right is one that was discovered in New Jersey as a parasite in the Japanese beetle.

The nematode is multiplied in trays of chopped veal placed in the incubator shown at the left. Then the culture is scattered over the area where it is desired to infect the beetles. As many as 15 million nematodes can be grown in a tray.

and eighty species of plants have been listed that are infected by them. The eggs hatch in the soil and the young worms penetrate the roots, living on the juices that they suck from them. They cause large swellings on the roots and may even kill the host plant. Among the plants attacked by them are red clover, the peach, tomato, cabbage, raspberry, and fig. Adult worms and eggs are easily spread in shipments of plants. But for the root nematodes, the fig would be commonly grown in our Southern states. In that region the cultivation of the raspberry and of many other plants is seriously hindered by them.

Other roundworm parasites. The spine-headed or thorn-headed worms are degenerate intestinal parasites that have

no alimentary canals. One of them is common in the pig. There is an alternation of generations between the pig and the June beetle, and the pigs become infected by eating the large white grubs of the beetle. Many other roundworms are parasitic in the grubs of insects and one of these is proving valuable as a foe of the Japanese beetle. The legend of the illustration on the opposite page explains how this nematode is multiplied and distributed in the soil. Within three or four days after the grub (larva of the beetle) is attacked by the nematode, it dies. After completely devouring the dead body, the worms migrate back into the soil and await another host.

The horsehair worms, which are very slender, also belong to the roundworm group. They are at times found in watering troughs and occur abundantly at the edges of ponds and streams. Their slender shape has led to the mistaken idea that a horse's hair in water turns into a "horsehair snake." An Oriental species of hairworm—the Guinea worm—is 4 feet long and burrows beneath the human skin. Guinea worms have been supposed to be the "fiery serpents" of Old Testament reference. Most of the horsehair worms live a part of their lives as parasites in insects.

Many of the roundworms that are parasitic in animals begin their development in the soil and some of them can remain alive in the soil for several years. Both because of their parasitic habits and because of the sheer crude vitality of their protoplasm, roundworms hold an important place in the world of life.

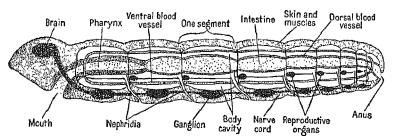
PROBLEM THREE

What Advances Do We Find in the Earthworm?

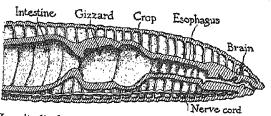
The earthworm is the familiar representative of the annelids, or segmented worms. Our common species reaches a length of about a foot. One in Tasmania grows to be an inch in diameter and 4 to 6 feet long. In the earthworm we are studying an animal that is far above Planaria in the life scale. It is a much larger animal and its structure is more complex.

General plan of the earthworm body. The earthworm has a mouth at the head or anterior end and an alimentary canal that extends entirely through the body. It has a circulatory system. It has an excretory system for the removal of cell wastes. It has a brain and a nerve cord that extends back from the brain through the entire length of the body. It has two sets of muscles, one running lengthwise of the body and one running circularly around it. There are no special respiratory organs. Oxygen is taken in and carbon dioxide is given off through the moist skin.

One of the distinguishing features of the earthworm body is that it is made up of sections, or segments. As the illustrations show, there are partitions which at the joints extend inward from the outer body wall to the alimentary canal. These cut the body up into disk-shaped sections that are coupled together in freight-train style.



The segmented worms are built on the unit plan. The units, except the ones at the ends of the body, are much alike. The alimentary canal, the nerve cord, and the circulatory system extend through the whole body.



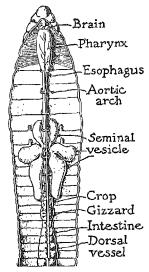
Longitudinal section of the fore part of the body of an earthworm.

Each segment has its own muscles and a pair of kidney tubes called *nephridia* (singular, *nephridium*). Each is in some respects like a complete animal, but the alimentary canal and the circulatory system are common to all the segments. In each segment the space between the alimentary canal and the body wall is filled with liquid.

Digestive system and food of earthworm. The alimentary canal of the earthworm is made up of the gullet, crop, gizzard, and intestine. As in birds, the crop softens what has been eaten and the thick-walled muscular gizzard grinds it up.

The earthworm makes its burrow chiefly by eating its way through the soil. It swallows the soil as it goes. As it works through the soil in this way the worm takes in a large amount of material, which passes through its alimentary canal and is thrown out near the mouth of the burrow as "castings." The earthworm obtains a considerable part of its food from the organic matter that it digests out of this material. It eats also grass and leaves, sometimes dragging them into its hole. To get these it comes out of its burrow at night, usually leaving the tip of its tail in the burrow and exploring the surface of the ground as far as it can reach.

Circulatory system. A large animal—and especially a land animal—must have some system for carrying food and oxygen through the body. The earthworm has such a system. It has blood and blood vessels that reach all parts of the body. One large vessel lies along the back and one on the lower side of the body. In the dorsal vessel blood flows forward, passes down



Organs in the fore part of the body of an earthworm as seen from above.

by five aortic arches near the front of the body, and flows backward in the ventral vessel. Smaller blood vessels running upward in the body connect the two great vessels. There is no heart, but the dorsal vessel and the aortic arches contract rhythmically like a heart and drive the blood onward.

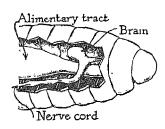
Hemoglobin (hē'mo-glō'bĭn) is the name of the chemical that gives the red color to blood. In our blood the hemoglobin is in the red corpuscles. In the earthworm the hemoglobin is dissolved in the liquid (the plasma) of the blood. The only corpuscles present are white ones.

Nervous system. In the head of the earthworm there is a brain, and

from the brain a large nerve cord runs back through the body. This lies on the lower side of the body and not along the back as in the vertebrate animals. In each segment of the body there is a swelling on the nerve cord — a ganglion, or collection of nerve cells. The white nerve cord, which you can easily examine for yourself, is a chain of ganglia connected to each other and to the brain. Each ganglion acts as a little local brain in the control of its own body segment. The whole row of ganglia, acting together and with the brain, controls the body as a whole. The form of the nervous system is adapted to the body form of the worm.

The nervous system of the earthworm is of course of a low order, but yet an earthworm has memory. By use of a T-shaped apparatus that will give an electric shock if a worm turns in one direction and not in the other, a worm can be trained to make a right or a left turn. Further, if a trained worm is cut in two and the back part is allowed to grow a new head and new brain it will still remember how to make the turn. Evidently memory in the earthworm is not confined to the brain.

How an earthworm crawls. If you will pass your finger along the side of an earthworm you will note a distinct roughness of the skin. You are feeling the setae (sē'tē; singular, seta), stiff bony little pegs that are set along the sides of the body. Four pairs of these — two pairs on either side — are found on each segment. They stick out like little pins from the body wall



Dissection of the head of an earthworm, showing the brain and the nerve cord.

and keep the animal from slipping as it crawls. Perhaps you have tried to pull an earthworm from its burrow. It is the setae that enable the worm to hold on as it does.

When an earthworm crawls, it sets the setae to hold the front end of the body. Then by contracting the longitudinal muscles it shortens itself and draws the back end forward. Next it adjusts the setae to hold the back part of the body and contracts the circular muscles, squeezing the liquid in the body and shooting the front part out forward. By changing the direction in which the setae point and thus reversing the ends of the body that are anchored, it can back up. By contracting the longitudinal muscles on one side only, it can turn to the side. All the movements are coördinated and the different muscles are made to work together by the nervous system, which reaches all the body parts.

Reproduction. Reproduction is sexual and each animal is bisexual. Each produces both eggs and sperms but the eggs are not fertilized by an animal's own sperms.

If you will examine a worm you will see that the front part is slender and that about thirty segments back from the anterior end in mature worms is a thickened band or region of the body. This is called the *girdle*, or *clitellum* (klǐ-těl'um). About halfway between the clitellum and the anterior end, on the lower side of the body, each worm has four little pockets. In the breeding season two worms come together and each fills the pockets of the other with sperms.

Before the eggs are laid a slimy coating is secreted about the



The thickened part of the body (about thirty segments back from the anterior end) is the clitellum or girdle. It secretes a sticky substance that hardens into a capsule in which the eggs are deposited.

girdle. This coating hardens into a skin-like sac which slips forward over the head of the worm. As the sac passes over the openings from the ovaries in the fourteenth segment (counting back from the head), eggs are laid into it. Sperms from the pockets are discharged in among the eggs. Then the sac is slipped off over the head and left in the ground as a sort of cocoon in which the eggs are fertilized. Within the capsule the eggs hatch and then the little worms emerge. In 90 days after hatching, they have developed to the egg-laying stage.

Abundance and importance of earthworms. Earthworms are not abundant in heavy clay soils; in soils that are rich in vegetable matter they are present in enormous numbers. Charles Darwin studied them for 40 years and concluded that there are perhaps 50,000 of them to an acre of land; that they bring up and cast out on the surface of the land 18 tons of material to an acre each year; and that in 20 years they would cover a field with a deposit 3 inches deep. He mentions a stony field that



In fertile land there are perhaps 50,000 earthworms to the acre.

in 30 years was so covered with a layer of fine material that "a horse could gallop over the compact turf and not strike a single stone with its shoes." Earthworms work into the soil to a depth of 6 feet and by boring holes that help drainage and ad-

mit air and by bringing up to the surface mineral food materials for plants, they have a great agricultural effect.

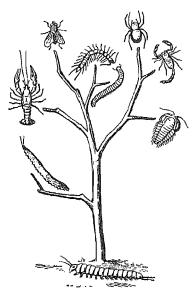
The earthworm absorbs oxygen and gives off carbon dioxide through its moist skin. It lives only in damp soil and comes out on the surface of the soil only when the air is moist and cool. It goes from light to darkness, and in winter in cold climates it burrows in the ground deep enough to escape the frost. It is eaten by shrews, mice, and robins. Being captured by an enemy is not always fatal to it; if a robin gets half an earthworm, the half that escapes will soon grow into a complete worm. The earthworm furnishes a splendid example of the survival of the unlike. Because there is no other animal that lives and feeds as it does it escapes much of the danger and competition that many other animals must meet.

PROBLEM FOUR

What Are the Characteristics and Relationships of the Arthropods?

The arthropods are probably descendants of worm-like ancestors. The body is segmented and the nerve cord is located in the ventral side of the body as in the earthworm. Externally the great advance in the arthropods over the worms is in the jointed limbs and skeleton. These along with highly developed muscular and nervous systems enable the arthropods to lead an active life. The air-breathing kinds have tracheae or lung books and the water forms have gills. The characteristics of the important living arthropod groups are set forth on page 991.

The primitive arthropod. The arthropods are a very ancient group and we have no geological record of their origin.



The arthropod family tree. The first arthropods are supposed to have been segmented, worm-like animals similar to the form shown at the foot of the tree.

In many body features they are like the segmented worms and the first arthropods were probably worm-like in form. drawing at the foot of the arthropod tree shows in a general way what the primitive arthropod is supposed to have been like. Supposedly the segments throughout the entire length of the body were practically alike. Each segment carried a pair of jointed appendages. If a clamworm (page 989) were provided with jointed limbs it would have the same general form that the first arthropods were supposed to have had.

In most living arthropods the segments in different parts of the

body are very different and in many species only a part of the segments carry appendages. Some living kinds, however, are probably much like the primitive arthropods in general body form. There are several orders of primitive wingless insects in which the segments of the body are more alike than they are in the more advanced insects. The figure at the right shows one of these. It is called the silver fish and may be recognized by its glistening scales and three long tails.

The arthropod skeleton. Characteristic of the arthropods is their jointed exoskeleton (Greek exo, outside, + skeleton, skeleton; outside skeleton). In them the skeleton encloses the

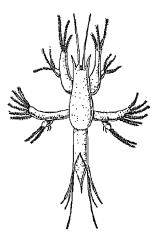


The silver fish, a primitive wingless insect.

body as a hard casing to which the muscles are attached from within. This arrangement gives to the arthropod not only a skeleton for the attachment of its muscles as they work but also a

protective body covering. To a considerable extent the arthropods have the advantages of both the armor of the shelled mollusks and the movable skeleton of vertebrates like ourselves. The body covering of the arthropods is composed of tough horny *chitin* (kī'tǐn). In the larger crustaceans (crayfish, crab, lobster) the coat is thickened and hardened by a deposit of lime.

Moulting and metamorphosis. A result of having the body enclosed in a hard covering is that as an arthropod grows it must from time to time moult, which means that the animal slips out of its inelastic casing and proceeds to grow a bigger one. Connected with this moulting there may be a metamorphosis, or change of form.



A young shrimp. Compare it with the form of the adult animal shown on page 851. Like the insects the crustacea moult from time to time as they grow and many of them undergo great change in form.

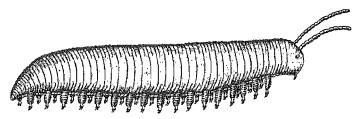
You are familiar with the metamorphosis of insects—the change of caterpillars into butterflies, or wrigglers into mosquitoes, and of maggots into flies. Many crustaceans go through changes almost as complete. The young of crabs are so different from the adults that for a long time they were supposed to be different species. Perhaps you have watched a moth emerge from its cocoon and have seen the chitinous shells that are left by cicadas (sǐ-kā'das) when they moult.

The myriapods. The Class Myriapoda (mĭr'ĭ-ăp'o-da; Greek myrias, ten thousand, + pous, foot) includes the millipedes (thousand-legged worms) and the centipedes. In them the segments throughout the whole body are practically alike. Like the insects and spiders, however, the myriapods have chitinous skins, tracheae, and jointed legs. Geologically they are older than the insects; that is, they are found in lower rocks.

The millipedes have round bodies and from twenty-five to more than one hundred segments, depending upon the species. They have two pairs of appendages on each segment, but notwithstanding the great number of legs they move slowly. They live in moist, damp places (sometimes being abundant in greenhouses) and eat vegetable matter. They curl up when alarmed or surprised and some of them as a means of defense give off a substance with a bad smell. Some species scrape out little nests for their eggs and stay with the eggs until they hatch.

The centipedes are made up of five to one hundred and fifty segments. Instead of having round bodies like the millipedes, they are flat. They may be found under stones or loose bark and small ones are often seen in houses. They have a single pair of legs on each segment and are quick in their movements. They are meat eaters and back of the mouth have a pair of "poison claws" which are hollow and, like the fangs of snakes, are connected with poison glands that empty into them. With these claws the centipedes seize and kill insects and other small animals. The tropical ones may be a foot in length. Their bite may be very painful to man, but it is not fatal. Centipedes have a pair of long antennae on the head.

Peripatus. In scattered areas in the tropics there occurs a curious little animal that very definitely connects the arthropods and the worms. It is called *Peripatus* (pe-rĭp'a-tus). It has a soft, worm-like body and like the jointed worms it has a pair of kidneys in each segment of the body. It has, however, unlike the worms, a pair of jointed legs on each body segment, and like the land arthropods it has tracheae for breathing air and a chitinous



Peripatus, the most worm-like of all the living arthropods.

covering over the body. It is 2 inches or more in length and lives in dark places, feeding on ants and other insects. A curious weapon is a pair of "slime" glands from which it can squirt a sticky substance a foot or more to entangle its prey. It is of no importance except as a living connecting link between arthropods and worms.

Peripatus is an example of an organism with a discontinuous distribution. It is found in areas in the West Indies, South America, Mexico, and the Pacific islands, but not in between these areas. Its scattered distribution is accounted for by supposing that it is an old form that at one time was widely distributed over the warmer parts of the earth and has now died away except in a few spots.

Neither the Myriapods nor Peripatus can be supposed to be the ancestors of the insects, spiders, or other living arthropods. They are supposed to have branched off from early air-breathing forms and each to have been modified in its own way. They do, however, show worm features and many insects in their larval stage have the general form of a worm.

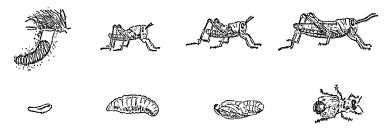
PROBLEM FIVE

How Do We Account for the Astounding Success of the Insects?

The greatest branch of the land arthropods is the Insecta. There are more species of insects than of all other animals combined, and the individuals of a single species are often innumerable. In some kinds the body form varies greatly according to the stage of development. The study we shall make is of the adult body form.

Metamorphosis in insects. Some of the insects, such as grasshoppers, gradually change their form from moult to moult as they grow. They are said to undergo incomplete metamorphosis. In other insects we recognize four distinct stages — the egg, the larva, the pupa (often a resting stage), and the adult form. Such insects are said to undergo complete metamorphosis.

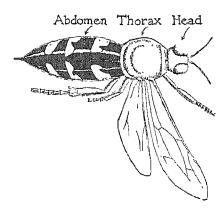
The larvae of the flies and bees are footless maggots. The larva of the butterfly is a caterpillar. Larvae of many beetles are grubs. The change from the larval to the adult form is made by the rebuilding of the body. When a maggot changes to a fly the tissues of much of the body are broken down and rebuilt in the form of the adult fly. Out of the material already in the body of a caterpillar the wings of a butterfly are developed while the larva rests in its cocoon. It is in the larval stage that insects go back to



The grasshopper gradually changes its form from moult to moult — undergoes an incomplete metamorphosis. The bee has distinct life changes and at some of its moults undergoes a very marked metamorphosis.

the worm-like form of the primitive arthropods. Many insect larvae are popularly called worms.

General features of insect body. The body of an insect has three divisions, head, thorax, and abdomen (ăb-dō'mĕn). The thorax bears appendages—three pairs of legs and sometimes wings. The number of legs is always six. Some-



The three divisions of the insect body.

times the insects are classified as the Hexapoda (hĕks-ăp'o-da), which means the six-footed ones.

Some kinds of insects are wingless; some (e.g., flies, mosquitoes) have two wings; the typical insect has four wings. In the adult insect only the thoracic segments carry appendages. Some of the larvae have legs on other segments also.

The mouth parts in the different orders of insects vary greatly, but in a general way they are fitted for biting and chewing (grass-hoppers, crickets, beetles, dragonflies); for sucking (housefly, bee, butterfly); or for piercing and sucking (mosquitoes, biting flies, fleas, plant lice, "bugs").

Respiratory and circulatory systems. The insects have a respiratory system that for a small animal at least is certainly better than ours. There are no lungs, but along the sides of the body are small openings called *spiracles* (spī'ra-k'ls) that lead into *tracheae* (page 334). These are branching tubes made of chitin with springy rings in the walls that keep them open. They run everywhere through the body, branching again and again into little twigs that reach all through the tissues. The insect breathes by squeezing on the tracheae to force the air out and then letting them spring open to draw the air in. From the air in the small branches of the tubes the cells get their oxygen; and into the tubes the carbon dioxide formed by the cells is given

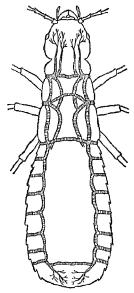


Diagram of the main air tubes in an insect's body. The arrangement differs in different insects.

off. Thus the air is piped through the body somewhat as water is piped through a city. The arrangement of the main air tubes differs in different insects. In the honeybee and other strong fliers much of the space within the body is occupied by large air balloons.

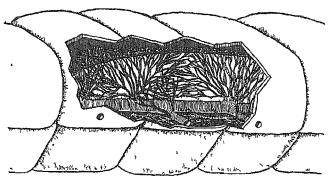
An insect has a circulatory system, but the plan of running the respiratory tubes all through the body makes the work of the heart and blood comparatively simple. An animal with lungs or gills takes in its oxygen and gives off its carbon dioxide all in one place, and there must be a rapid and incessant pumping of great volumes of blood to distribute the oxygen and carry away the carbon dioxide from the cells. In an insect the larger blood vessels go only to the head, where the tracheae are not abundant. There must be a circulation

of the blood to distribute food and carry away cell wastes, but the heart is not worked as it is in many other animals.

Nervous system and sense organs. The nervous system of an insect is on the same general plan as that of an earthworm. There is a brain in the head and a nerve cord along the lower side of the body. Many of the insects, however, have better brains than the earthworm. The insect has also a set of sense organs that give the brain information about the outside world.

The most highly developed of these sense organs are the eyes, which are of a kind very different from the vertebrate eye. They are compound eyes built up of a great collection of little eyes. The insect eyes cannot be focused as our eyes can, but nevertheless they serve their purpose so well that a dragonfly or hornet can catch a fly or mosquito on the wing. The eyes of insects form real images and in some kinds cover so much of the head that the insect can see in all directions.

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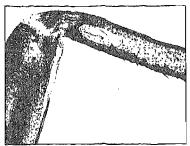
The larger tubes of an insect's air system have many side branches. These divide again and again and form a fine meshwork all through the body.

Many insects have also a wonderfully acute sense of smell. Some have primitive "ears," which consist of organs in hollows in the legs or bodies with membranes stretched over them. Insects do not have vocal cords and voices as frogs and birds and humans have, but certain of them by rubbing movements of the wings or legs make chirping or buzzing sounds. Most animals live as silently as the plants do. Some of the insects have developed up to the world of hearing and of sound.

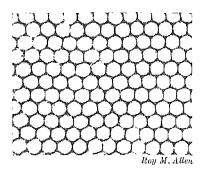
Reproduction. Reproduction among insects is by eggs and sperms. The parent animals are unisexual — male or female. Among the social insects, however, we find individuals that are incomplete in their sexual development, forming a neuter class or classes that serve as workers or as warriors for the protection of the colony. In general insects are short-lived and to keep up the population there must be much rearing of young. One of the longest-lived insects is the seventeen-year locust (cicada) which spends seventeen years underground in larval form.

Advantages in the insect plan. The insects are the most successful of the land animals, and of all animals. To what do they owe their success?

First, they have a great advantage in their protective chitinous coat. The insects are lucky to have a coat that serves both as a skeleton and as a protection from hurts and germs.







The ear of a cricket and a portion of the cornea of an insect's eye. insects, like the vertebrates, have highly specialized sense organs that give them information of the outside world.

A second advantage that they have is in their respiratory apparatus. By its system of dry, chitinous, and usually germproof tracheae that reach all through the body the insect avoids the long list of troubles that we have with our tonsils, respiratory passages, lungs, heart, and arteries.

A third advantage that many insects have is in their complete change of form through metamorphosis. The grub of the June beetle or of the cicada lives during its defenseless period in the earth. Then the final moult comes and the adults emerge as winged animals that can escape their pursuers by flight and can range over a wide area to find a favorable place to lay their eggs. There is an advantage in a hidden, obscure life during the helpless immature stages and an active adult form that will spread the species over a wide range.

A fourth advantage of the insects is in their power of vast multiplication. They lay many eggs and these develop quickly. In a season a single pair of most kinds of insects can increase to multitudes and if conditions become favorable for insect life the insects can multiply and take advantage of them, "A termite queen can lay eggs at the rate of one a second without intermission for 30 years."

A fifth advantage held by the insects as a class is in the number of new forms that appear. The protoplasm is variable; the generations follow each other in rapid succession; a tremendous

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number of young are produced. Insects have an unusual opportunity for the development of new kinds and they produce a multitude of different forms that are fitted to many different conditions. Grasshoppers pasture in the fields; the bee lives on pollen and nectar; dragonflies catch mosquitoes; the flea sucks blood; the termites and borers feed on wood; the bookworm eats paper and the clothes moth eats wool. There are insects that live in water with a heat of 170° F. and the young of the snow fleas develop on cakes of ice. It is interesting to note that after the citrus growers of California had used a poisonous gas for some years to kill the scale insects on their trees varieties of the insects that were resistant to the gas appeared.

A sixth advantage that the insects have is that they and their relatives (spiders, scorpions, mites) are the only small animals of any importance on the land. If we leave out of account the land snails, these are the only invertebrate animals that are fitted to come out into the sunlight and air. They can withstand drying. They breathe air. In the egg or larval form they resist cold.

Away back in Paleozoic time the insects found on the land a great domain practically uninhabited by other animals and by fitting themselves to it they have prospered in an amazing way. Insects meet competition from other insects, but they do not have the fierce competition from other small forms that the animals of the sea must meet.

The Homer of the insects. The poet Homer sang the deeds of the ancient Greeks in their war at Troy. The insects also have their Homer who came to fame through his writings on insect lives and insect ways. This recorder of insect



J. Henri Fabre, who achieved fame without seeking it, by studying insects and recording in beautiful language the results of his observations.

activities is Henri Fabre, who was born and lived in the south of France. He wrote in prose, but there is much of the poet's spirit in his works.

J. Henri Fabre was born in 1823, and he died in 1915 at the advanced age of ninety-two years. He was a teacher and added to his small income by writing. Finally he was able to retire from teaching and give all his time to study and writing. He regretted that he was not able "to travel over the world, by land and sea, from pole to pole; to cross-question life, under every clime in the infinite variety of its manifestations." He could not afford visits to remote regions, however; so he devoted himself to the study of the insects he found on his own small estate. Of himself and his work he writes:

"I go the circuit of my enclosure over and over again, a hundred times, by short stages; I stop here and I stop there. The smallest insect village has become familiar to me. I know each fruit branch where the praying mantis perches; each bush where the pale Italian cricket strums amid the calmness of the summer nights. I patiently put questions; and at long intervals I receive some scrap of a reply."

In the works of Fabre you will find fascinating accounts of insect behavior. His observations do not always receive the same interpretations as he put on them, but the observations themselves are accurate. His writings were long familiar only to other students of insects and it was only in his old age that the public discovered and acclaimed them. Then it was realized that this humble student of insect life by recording his observations in beautiful language had made "a noble contribution to the literature of France." A great banquet was given to him in 1910 at which a speaker recited an account of his life and work. "Moved to tears by his memories and by the simple pious homage at last rendered to his genius, Fabre wept, and many, seeing him weep, wept with him."

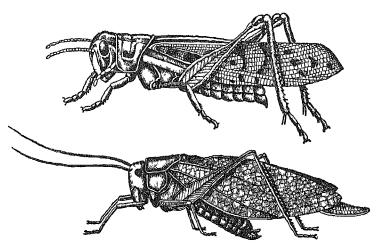
PROBLEM SIX

What Are the Life Histories of Some Representative Insects?

We can study in a brief way the development and ways of living of only a few insects and must allow these forms to serve as representatives of the whole insect group. We shall start with the grasshopper, which is one of the insects that gradually change in form from moult to moult as they grow. Then we shall take up the housefly, the mosquito, and the wasp, which in their metamorphoses undergo at one time a complete change of form. These insects are familiar ones and they are important to man.

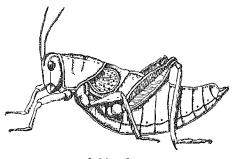
THE GRASSHOPPER

The grasshopper belongs to the Order Orthoptera (Greek orthos, straight, + pteron, wing; straight-winged). This is an old order which has existed since the coal age. The crickets and cockroaches belong to it. All the members of the order have four wings.



Grasshopper and katydid. The grasshopper here shown is a short-horned locust and the katydid is a long-horned one.

Kinds of grasshoppers. In zoölogical writings grasshoppers are called locusts. There are two families of them, the short-horned and the long-horned. Certain slender green grasshoppers (meadow grasshoppers) and the katydids belong to



A lubber locust.

the long-horned family.

There are 550 species of grasshoppers in the United States, but only a comparatively few kinds are found in any one locality. One large kind that is widely distributed is the Carolina locust. In this species the underwings are black with a

wide yellow border. The males flutter up and stand poised in the air, "singing" or "crackling" to attract mates. Another common kind is the red-legged locust, which is not so large and has a red stripe on the outside of the leg. In the southern part of our country a large, short-winged, heavy-bodied species called the lubber locust is commonly found.

Nutrition of grasshopper. The grasshopper feeds on grass or other tender vegetation. It hops about, seemingly in an aimless way; but its food is widely distributed and its journeys land it sooner or later where it can eat. Its jaws, or mandibles, which work sidewise, are well suited for pinching off mouthfuls from a blade of grass or corn or from a tomato or apple. After the food is swallowed it is taken into a crop where it is softened with a brown digestive liquid ("tobacco juice," or "molasses"). Then it goes to the gizzard, where a gastric mill made up of little horny plates on the gizzard wall reduces it to pulp. Grasshoppers drink from drops of dew or rain on vegetation or other objects. In captivity they will not drink from a vessel of water and will die of thirst unless water is sprinkled about.

Escape from enemies. Far more difficult for the grass-hopper than obtaining food is the job of escaping from enemies.

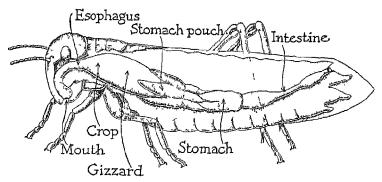


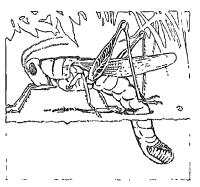
Diagram of the alimentary tract of a grasshopper. Within there is more of a division between the crop and the gizzard than shows from the outside. The stomach pouches secrete digestive juices and empty them into the stomach.

Skunks, toads, snakes, and especially birds feed on grasshoppers. Wasps, robber flies, spiders, and certain beetles prey on them. Their coloration helps to make them inconspicuous. "Green grasshoppers are ordinarily found in the midst of green foliage, striped ones in meadows and open fields, and brown and gray ones in dry or semidesert regions, or on bare ground." Try to see a grasshopper after it alights from a hop and you will appreciate how well they are concealed. The red-legged locust, if surprised, will quickly turn itself lengthwise of a grass blade or it may drop to the earth and hide.

If caught, a grasshopper kicks and struggles and "spits tobacco juice." If a leg is broken off the grasshopper seems not to be injured and if it is young enough to moult again it will get a new leg the next time the exoskeleton is shed. A small enemy of the grasshoppers is a red mite which sometimes fastens on them and sucks the juice from their bodies. Not infrequently you will see these as red dots in the joints of the body. A parasitic fly (tachina fly) lays its eggs in the grasshopper, and horsehair worms (page 321) are found in them. There is also a fungus that causes great epidemics among the grasshopper population. Notwithstanding the dry chitin of which the tracheae are composed, this fungus can grow in them and in wet years the disease may be very common.

It is not the lack of food but other living things and the destruction of the eggs by cold and too much moisture that holds grasshopper life in check.

Reproduction. The female grasshopper lays her eggs in the earth. First she works out a hole with the back end of the



Female grasshopper depositing a packet of eggs.

abdomen. Then she deposits in the opening a packet of thirty or forty eggs. The adult or partially grown individuals of some species may live through the winter, but in many kinds only the eggs survive. In the spring these hatch in wingless form. They feed and moult and with each moult larger and larger wings appear until full size is reached.

The young that come from the eggs of kinds that do not live through the winter never see their parents. They must know how to hop, feed, drink, and hide from their enemies, without anyone's teaching them. If they succeed in life the credit is theirs. If they fail they cannot blame it on the way their parents brought them up. In human beings it is in most cases practically impossible to know what we should credit to a person's protoplasm and what to his training and opportunities. In spring-hatched grasshoppers, whose parents died the fall before, the effects of "nature and nurture" are easily separated. Since the ones that hatch first in the spring act the same as those that come out later and associate with their elders, we must conclude that grasshopper conduct is determined by heredity rather than by training.

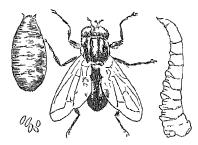
Grasshopper invasions. The swarms of grasshoppers that travel and eat all before them are migratory kinds that breed in grasslands. Favorable conditions for the survival of adults and eggs may allow them to come out in such numbers that the local food supply is insufficient. When this is exhausted they

take to the air and invade new territory. In our own country they breed in the Western plains. In the wet tropics they come from areas where the trees have been cut and grass has come in. In South America and Africa the natural grassland regions are breeding places for them. To prevent the damage they do to

agricultural crops and pastures, the young are poisoned, trapped, or killed in other ways.

THE HOUSEFLY

The housefly belongs to the Order Diptera (Greek di, two, + pteron, wing). You can easily distinguish flies from small bees or other insects that might resemble them by the fact that



The four stages in the life history of the housefly.

they have two wings. Not all the flies that you see around a house are true houseflies. Stable flies, bluebottle and greenbottle flies, blowflies, cluster flies, and vinegar flies may appear. But the houseflies are much the most numerous.

Reproduction of housefly. Houseflies breed preferably in horse manure although they will also lay their eggs in the droppings of other animals, in human excrement, or in decaying vegetable material. A female housefly lays from 120 to 150 eggs at a time and usually lays 2 to 4 such batches at 8- to 10-day intervals. These eggs may hatch in as little as 8 hours into footless larvae which are called maggots. After 4 to 7 days the larvae pass into the pupa stage, which lasts another 3 to 6 days. The mature flies when they emerge crawl about until their wings are dry and then take up their adult life. The new females may lay eggs within $2\frac{1}{2}$ days or they may be delayed as long as 20 days. The average time for the maturing of a generation of flies is approximately 14 days. It is easy to understand that in one summer the offspring of a single fly may become a multitude.

Flies as disease carriers. Because flies crawl over and feed upon all kinds of animal wastes they are a real menace to our

health. They have been proved to carry typhoid bacilli as well as the germs of dysentery, Asiatic cholera, and diarrhea. There is also good evidence that they carry the germs of tuberculosis and the virus of smallpox as well as the eggs of such parasitic worms as the tapeworm. Medical science indicts the fly as the carrier of some thirty kinds of disease organisms. Its hairy feet become laden with germs and where water sewage is lacking it is highly important that human wastes be covered from flies.

Methods of controlling flies. The fight against these human enemies should center upon the removal of their breeding places. Manure can be so disposed of in manure pits as to be inaccessible to adult flies; or if it is spread thinly on the fields once a week the eggs and maggots will die in the sun. Garbage, too, and heaps of vegetable matter must be covered or removed. All possible breeding material should be destroyed or rendered inaccessible to flies.

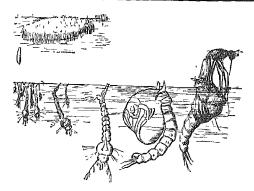
Screening of houses, use of sprays, flypaper, flytraps, and swatting the first flies of the season are familiar and important means of fighting flies. In spite of all our efforts we still have in the country and in smaller towns immense numbers of flies every



year. They constitute a problem that challenges man's ingenuity for solution. Removal of any water that flies may drink and placing a vessel of milk with a little formaldehyde in it outside of doors or on porches where flies congregate is often an effective way of decreasing their numbers. The formaldehyde keeps the milk from thickening and is poisonous to the flies.

A number of electric insect killers are on the market. Some of these devices, when placed on house porches or in stores or kitchens, are a very important aid in fly control.

An electric insect killer. The light from an electric lamp within the wires attracts the insects. The current switches on and off so that electrocuted insects drop from the wires.



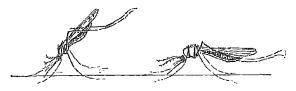
Three stages in the life history of the mosquito.

THE MOSQUITO

The mosquito more than any other living creature has driven man from great areas of the earth. Where breeding places are favorable and abundant, mosquitoes may appear in such numbers that men and other animals on which the mosquitoes feed cannot live among them. In addition the mosquito is the alternate host of two of the worst human parasites, the germs of malaria and of yellow fever. All regions where these diseases prevail, no matter how rich the soil or what natural advantages they may possess, have few human inhabitants.

Life history of mosquito. The young of the mosquitoes, although they breathe air, live in water. The larvae are called "wrigglers" or "wiggle-tails." They feed on small plant and animal life and come to the surface for air, which they take in through breathing tubes at the tail. After a short time the fore part of the body thickens and the breathing tubes shift to the back. The larva has turned into a pupa, which is called a "tumbler" because it tumbles over and over in the water as it swims. In 10 days, or longer, from the hatching of the egg the adult mosquito comes out. The length of time required for its development depends on the temperature of the water in which the larva and pupa live.

Controlling mosquitoes. The wrigglers and tumblers can easily be killed by a thin film of oil on the water. Small fish,



The malaria-carrying mosquito (Anopheles) and the common kind (Culex). The malaria mosquito has spotted wings and stands up on its head when resting or biting.

especially the top-feeding minnow, devour them and if vegetation in which they can hide is cleared away the fish will usually keep the mosquitoes under reasonable control.

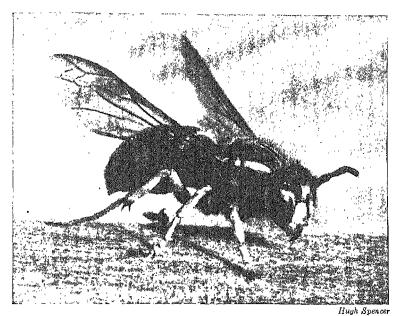
Different kinds of mosquitoes select very different kinds of breeding places and anyone desiring to enlist in an anti-mosquito campaign should secure information from his local health officer as to the best way to proceed. The malaria mosquito tends to breed in springs and clear streams. The yellow fever one is rather domestic, laying its eggs in rain barrels and other water near houses. One kind breeds in immense numbers in salt marshes and the "woods mosquitoes" lay their eggs in low places in the ground where the young hatch and mature in the spring in the pools formed by the water of the melting snow and the spring rains.

It is not possible to eradicate mosquitoes everywhere, but by



The yellow fever mosquito (Aedes). It is distinguished by light bands about the body.

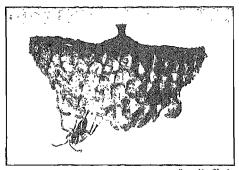
draining near-by swamps and looking after other breeding places cities can be rid of them. Many country homes raise their own mosquitoes in open rain barrels, cisterns, and tanks. It is a mistake to think of mosquitoes as insects of warm countries only. Parts of Alaska, Siberia, and other regions of high latitude have them in immense swarms. Their primary food is the juice of plants; and where mosquitoes are troublesome, tender vines and tall grass should not be allowed about dwellings.



The death that flies. If Siberian tigers had wings they would be no more terrible to us than wasps are to other members of the insect group.

THE WASPS

Some of the wasps are solitary and some are social (live in colonies). Many of the solitary ones rear their young in mud nests or in burrows in the earth which they stock with spiders or insects (page 253). Some of them lay their eggs in the larvae of insects and the young develop parasitically. The social wasps (hornets, yellow jackets, paper wasps) build nests of paper which they scrape from wood. They rear their young in the small apartments of the comb-like nests, the worker wasps feeding the young on chewed-up flies or other insects that they bring in. The adult wasps eat plant lice, flies, and other insects. nectar from flowers and drink the juices of ripe fruits. They may spend the night inside the nest or away from it, sleeping under a leaf or inside a flower. In the fall all except the young females die. These burrow in the ground or hide away in crevices and carry the race over to the next year.



Cornelia Clarke

Nest of paper wasp (*Polistes*). The young are reared in the cells of the nest and fed on chewed-up insects.

Wasps are a terror to spiders and to other insect life. They are to other small arthropods as hawks are to songbirds and the smaller mammals of the fields. Small insects they seize with their jaws and feet. Spiders and the larger insects the solitary wasps sting and carry to their nests as food for the young. One

wasp used seventy-seven houseflies in stocking a single cell. It was estimated that in a nest of a species that used the hollow straws of a strawstack as breeding chambers, six thousand spiders were stored.

Wasps are insects that most persons have the opportunity to study. The mud dauber and paper wasp build about houses and it is easy to watch them at work.

You will find it interesting to keep some living insects in the school laboratory or in your room at home and study their habits and development. A cricket, katydid, or grasshopper makes a good pet. Mosquito wrigglers are easily found and reared. A fly can walk upside down on a piece of smooth glass in a rather wonderful way. A study of these small creatures that share the land with us reveals in them a fascinating array of adaptations for the lives they lead.

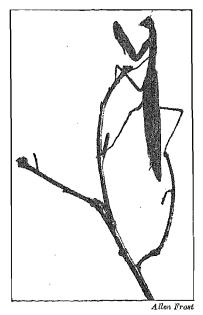
PROBLEM SEVEN

What Measures Are Used to Keep Insects under Control?

Over vast areas of the tropics the insects win in their contest with man for possession of the land. By their biting power and the diseases they carry they hold to a very low figure the human population over a great part of the warmer regions. In the

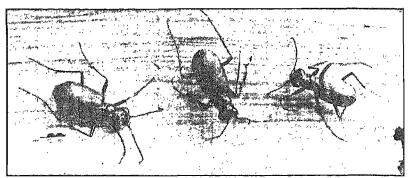
temperate regions man is more successful. Yet in spite of the never-ceasing war that we carry on against them the insects take one tenth of our crops and are a pest to us in many ways. The whole problem of insect control is one of the major problems of mankind.

Predatory insects. Kipling tells about the other animals going to the dog and remonstrating with him because of his traitorous conduct in joining the enemy, man. The insects might with equal propriety argue against the conduct of some of their kind, for the great ally of man in his war against insects is other insects. Most insects that become very abundant have other insects that prey on them,



A praying mantis, which should be named the *preying* mantis. If an insect comes within reach, the long barbed forearms will seize it and the scissor-like jaws end its career.

and when a new field or orchard pest is introduced it is customary to send scientists to the native country of the invader to find what insect enemies there hold it in check. Birds are great foes of the insect world. Other larger animals help keep their numbers down. Still more important are the tiger beetles, dragonflies,



Cornelia Clarke

Tiger beetles. They are appropriately named. Both the larvae and the adults are fierce beasts of prey. The long legs of the adults make them swift runners. They have a brilliant greenish metallic color.

wasps and hornets, robber flies, the praying mantis, the parasitic ichneumon (ĭk-nū'mon) and tachina flies that lay their eggs in other insects, and a host of other insects that live by destroying the more defenseless insect kinds.

Among the mammals of the land we have the herbivora feeding on the vegetation and the carnivora living on the plant-eating kinds. In the insect world also we have the herbivora and the carnivora, and but for the carnivorous ones man's problem would be much greater than it is. About one half of all species of insects are carnivorous and other insects are their chief food. Some insect pests can be controlled by the introduction of their natural insect enemies. Not the least important of the carnivorous insects are the ladybugs or ladybirds which feed on small helpless forms like scale insects and plant lice.

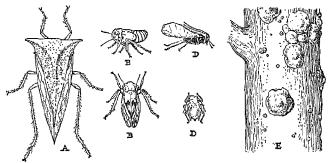
Other natural checks on insects. Many of the insects whose larvae pass their lives in the earth are infested with small roundworms. The worms are able to remain alive for long periods in the soil, and as the insect larvae feed and burrow about, the worms find opportunity for entrance into them. Many kinds of insects are greatly decreased in numbers by these worms. Some species of nematodes are of great aid in holding certain injurious insects within bounds (page 320).

Another natural check on insects and a very important one is

the smaller birds. By protecting the birds and providing them with nesting places the number of insects can be decreased. Spiders, centipedes, toads, snakes, shrews, and skunks are other insect enemies. Any increase in these means less of insect life.

Control by dusting and spraying. Some insects do not have effective natural enemies, and when these find large areas in a climate suitable to them planted to a crop on which they feed, they increase enormously. Examples of such insects are the Colorado potato beetle, the Mexican bean beetle, the European corn borer, and the codling moth and other insects which attack orchard fruits. Such insects must be controlled by artificial means and the most extensively employed method is the use of dusts and sprays. The chewing insects can be poisoned. Against the sucking insects that draw their nourishment from within the plant the chief defense is in sprays that kill by contact.

Thousands and thousands of tons of chemicals are annually used in spraying and dusting crop plants. The manufacture of these substances and of machinery for applying them is a great industry. Recently the airplane has been added to man's equipment for fighting his insect foes. With an airplane a man can dust a thousand acres in a day.



U. S. Dept. Agriculture

Small insects eaten by a small bird. The illustration shows three kinds of insects destroyed by the kinglet, the smallest of all our birds except the humming bird. A, tree hopper; B, young and adult leaf hoppers; D, winged and wingless forms of plant lice; E, scale insects — all three times their natural size.

Other methods of insect control. Japanese beetles are especially attracted by the odor of a chemical called geraniol (je-rā'nĭ-ŏl) and can be caught in large numbers in traps baited with this chemical. Male mosquitoes can be attracted to an electric apparatus that gives a fine whine of the same pitch as the "song" of the female mosquito and after they are attracted they can be electrocuted. It has been found that the grape leaf hopper is attracted by ultraviolet radiation, and an apparatus set up with an ultraviolet lamp in the center drew to itself and electrocuted two million leaf hoppers in a half hour. Very short radio waves intensively applied seem to kill animal protoplasm without harming plant protoplasm and there is hope that a broadcast of these waves through a greenhouse or garden can be made to free it of insect life.

Importance of the insect problem. The Superintendent of Public Documents at Washington issues a pamphlet in which are listed the government publications on insects. When we look through this we find bulleting dealing with dozens of kinds. The Department of Agriculture, the Forest Service. and the Public Health Service each has a group of scientists studying insects and reporting the findings to us. There are bulletins on insects that are enemies of field crops and of fruits and vegetables. There are other bulletins on insects that are destructive to lumber and forests. There are others dealing with insects that attack domestic animals, are household pests, or transmit human disease. There is even one on the Short-Circuit Beetle, which bores through the walls of lead cables and strips the insulation from the electric wires within. No other group of animals receives such attention from government scientists. Why is this? It is because insects are man's only real competitors. We need not worry about many of the animals of the sea, but the insects and man are both air breathers and they meet in direct competition for possession of the land.

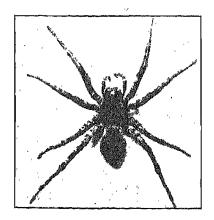
Hundreds of experts in nearly every nation are constantly planning new and more effective ways of killing man. If an improved method is found it is eagerly seized on and armies in every nation are at once trained in its use. A mere battalion of scientists stand guard against the insect foe. Yet insects hold many of the best parts of the earth. Thousands of square miles of the most fertile lands in our own country lie uncultivated because of them. They destroy our crops, pillage our gardens, torment our animals, annoy us, and infect us with disease. How should you like to enlist under the banner of science and help wage "a good war" against the insects for mankind? New discoveries, new methods, new fighters are needed. It is more fun to be a scientist and get into the fight than merely to read and hear about the wonderful things that scientists have done. A scientist who is an expert on insects is called an entomologist.

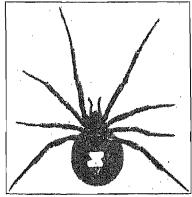
PROBLEM EIGHT

What Are the Characteristics and Life Habits of the Arachnida?

According to Greek mythology Arachne was the daughter of a dyer in purple and was very expert in the art of weaving. She challenged the goddess Athena to a weaving contest, and in the contest Arachne turned out a wonderful tapestry showing the metamorphoses of the gods and certain love scenes among them. Angered at not being able to find any flaw in this work, Athena tore it to pieces. Arachne in despair because of the loss of her masterpiece then hanged herself, but the goddess changed the rope into a silken thread and Arachne herself into a spider. Into her spider existence Arachne carried her ability and desire to spin and weave, and spider webs are the work of her descendants, who still ply her art.

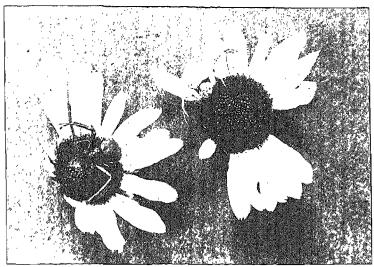
The Class Arachnida (a-răk'nĭ-da) gets its name from the spiders (Greek arachne, spider), but besides the spiders it includes the scorpions, ticks, mites, harvestmen (daddy longlegs), the





Black widow spider from Nature Magazine

At the left is a wolf spider, one of the hunters that range the fields in search of prey. At the right is the female black widow spider, one of the trappers. The hourglass-shaped marking on the lower side of the abdomen which identifies the female of the black widow spider is shown.



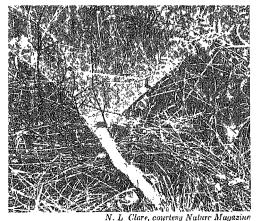
Cornelia Clarke

Two crab spiders waiting for their prey. The light-colored one rests on the petals of the daisy and the dark-colored one on the center. They seize butterflies, flies, and ants that visit the flowers.

horseshoe crab, and several other less familiar orders of small animals. The arachnids have four pairs of legs instead of the three pairs of the insects. In them the head and the thorax are fused into one part called the *cephalothorax*. The body is thus typically made of two parts, the cephalothorax and abdomen. The spiders are the most familiar animals of the group.

THE SPIDERS

The spider population is a heavy one and spider society is distinguished by its savagery. All the spiders are carnivorous. Each one gets its living either by hunting or by trapping. The females are the larger and among many of the species it is not unusual for one of them to make a meal of a male that comes to pay court to her. The eggs are laid in cocoons and the only note of softness in this whole killer society is the concern of some spider mothers for their offspring. These carry the cocoons about and care for them until the eggs hatch, and some species even carry their young on their backs.



Web of a tube weaver.

Hunting spiders.

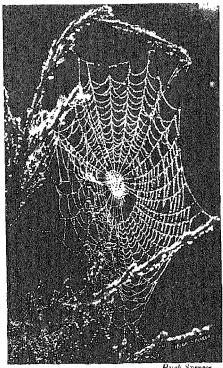
Not all spiders make webs; there is a multitude of "hunting" spiders that prowl the fields and lurk in out-of-the-way places, hunting and waiting for animals small enough for them to pounce on and kill. Different kinds of these are known as crab spiders

(which hide in flowers), jumping spiders, ground spiders, and running spiders. To land-animal life smaller than themselves they are what leopards and panthers are to larger forms. They are important foes of insect life.

The trappers. The web makers are trappers that spread their webs to entangle their prey. They are of several kinds. Some build irregular webs in corners and on bushes. The tube weavers construct a flat web with a tube at one side or below in which to hide. The line weavers string threads over stubble, grass, or bushes, and so abundant are they that sometimes in the morning a whole pasture or stubble field may be seen covered with their snares. The round-web weavers, or orb weavers, make the most scientific webs of all. When studded with drops of dew one of these webs is beautiful indeed.

Anatomy of the spider. Spiders have four pairs of walking legs. In front of these are two other pairs of appendages that serve as jaws and for seizing the prey. The first pair of these appendages are tipped with claws and in them are poison glands that discharge through the claws. The poison of a spider kills insects and other small animals. The female of one small black spider (the "black widow") has a bite that may even be fatal to man. It may be recognized by the red hourglass-shaped marking on the lower side of the bulbous abdomen.

Most spiders have tracheae and as has been stated they have in addition lung books (page 198). There are two of these on the underside of the abdomen. the spider the tracheae do not ramify through the body so completely as they do in insects and the spider has in its lung books additional organs of respiration. Near the back of the abdomen on each side are the spinnerets, the tops of which are pierced by dozens of minute holes. Through these openings the spider can squeeze a liquid which, when it comes to the air, hardens as a silky thread. In its web making the spider uses its back feet to guide the threads to the places where it wishes to place them. In the larval stage many insects can spin, but in the adults the spinning organs have been lost.

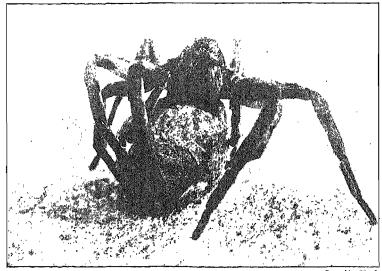


A masterpiece from Arachne's loom.

Spinning the web. The large yellow and black garden spider is common and if you watch you may have a chance to see it work. When it starts to make a web it first runs a thread around the space that it has selected, and then a cross thread. Then from a point near the center of the cross thread it runs out other threads so that they radiate like spokes from the hub of a wheel.

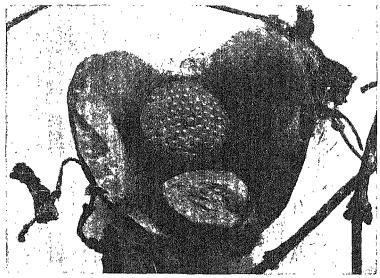
Then the spider lays a second set of threads across the radiat-It starts at the center of its web and goes round and ing ones. round, working in a spiral from the center out. It lays two strands of threads at a time, and when it has finished, the web is as regular as if an engineer had drawn the plan. There is no hesitation as the spider works. It knows what to do and how to do it.

After finishing the web the spider rests in the center of it or at one side. If an insect becomes entangled in the web the spider rushes to it and spins other threads about it until there is no



Cornelia Clarke

A mother spider guarding her cocoon. Spider society is one of savagery, but some of the mothers have the instinct to protect the eggs and young.



Cornelia Clarke

A cocoon opened, showing the egg mass. The eggs are packed in silk and the cocoon can be carried and dragged about without damage to them.

longer danger of its breaking away. It can spin two kinds of threads, one dry and one sticky. The first set of threads in the web — the radiating ones — are dry. The cross threads are studded with drops of a sticky liquid that help hold any insect that touches them. Different spinnerets are used by the spider in producing the dry and the sticky threads.

Reproduction. The eggs of the spider are laid in cocoons. a few or hundreds in one cocoon. When the young of some kinds are ready to scatter they have a way of climbing up on something and spinning a thread into the air. Then if the wind catches the thread and carries it away the baby spider gets a ride



Cornelia Curke

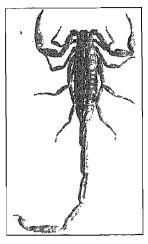
A young balloon spider preparing for the take-off. The wind catches the thread and carries the baby spider to a new home.

to a new home. It is a method of dispersion quite like that used by dandelion and other downy seeds. The threads of the young spiders are called "balloons." On a warm day in spring or autumn you may see dozens of them on a tree or fence. They are at times so abundant that they have been called "showers of gossamer." Spiders moult, but there is little metamorphosis. The young and old are much alike in form. The great enemies of the spiders are the wasps (page 348).

The harvestmen, or daddy longlegs, are relatives of the spiders. Their long legs enable them to run rapidly over grass and vegetation. They are active at night and they live by hunting insects as many of the spiders do. The eggs are laid in the autumn in the ground or under stones and hatch in the spring. Only a few of the adults survive the winter cold.

THE SCORPIONS

The scorpions have long, segmented abdomens which are divided into a thickened front part and a slender back part. Instead of poison glands in the jaws they have a sting loaded with



A scorpion, natural size. Like the centipedes and spiders, the scorpions are carnivorous.

venom in the tail. This serves as a weapon of defense and is used to paralyze the insects and spiders on which scorpions feed. As a group scorpions are larger than insects, measuring from ½ inch to 8 inches in length. They are animals of the tropics and subtropics, in our country being found in the Southwest and in the East as far north as North Carolina. The sting is painful to man and it has been known to be fatal to young children. The scorpions breathe by lung books and lack the tracheae of most other land arthropods. The young are born alive and for about a week after birth ride about on the mother's back. They become full grown in about five years.

The scorpions are a very old group. Long before the coal period there were sea scorpions (eurypterids) with an arm spread of 9 feet, and the oldest known land animal was a scorpion. The scorpions have survived through a long period, but they are not abundant as the insects and spiders are.

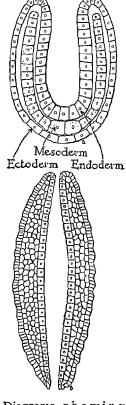
Other important Arachnidae are the ticks and mites. These are parasites and will be discussed in a later unit. Another arachnid is the horseshoe crab, which is a relative of the old trilobites and the lone survivor of a group whose other members long since became extinct (page 200).

RELATIONSHIPS OF THE ANIMAL PHYLA

In this unit we have studied two highly successful animal types, the worms and the arthropods. In the next unit we shall take up the vertebrates. Before beginning this study, let us pause to consider briefly the origin and relationships of the more important

animal phyla. As has been explained, the higher groups are all supposed to be descended from a common ancestral form and to be related to each other as are the branches of a tree. There are many reasons for accepting this belief, and one of them is the similarity in the first stages of development of all the animal forms above the coelenterates.

In their early development all higher animals go through the same stages as the hydra. In all of them there is first a single cell, then a ball of cells which becomes hollow, then a folding in of the cells at one side to make a cavity within the embryo. As in the hydra there is an ectodermal and an endodermal layer. In addition there is a mesodermal layer formed from cells that move into the center from the outer and inner layers. In the human body the skin, nervous system, and sense organs are developed from the ectoderm. The digestive tract, lungs, and liver develop from the endoderm. The muscles, the supporting tissues (bone, cartilage, connective tissue), and the circulatory system are from the mesoderm. In larger animals the mesoderm cells multiply until a thick layer is formed. Everything is more complex in the higher forms.



Diagrams showing plan of body development in higher animals. These have a third middle body layer not found in the hydra and other coelenterates (see page 305).

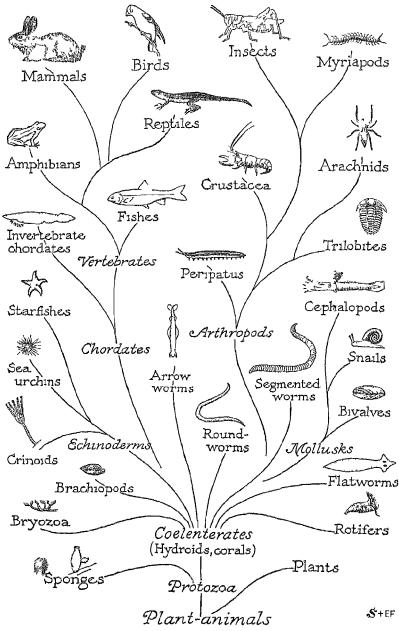


Diagram showing suggested relationships of the more important animal groups.

Now look at the opposite page. As the diagram shows, all the main animal types except one are invertebrates. Some of these (worms) have no skeletons. Some (sponges, corals, Bryozoa) have immovable skeletons that, like the hard tissues of plants, serve for support rather than to assist in movement. Some have shells outside the body which are protective only. The arthropods made a great advance with a jointed external skeleton and The vertebrates developed an internal jointed iointed limbs. skeleton which enabled them to grow to great size and become the ruling animals of both the water and the land. All the animals above the coelenterates, however, have three body layers in the early embryo stage; so they are all supposed to be akin and to trace back to a common origin.

It would be well for you again at this time to look over the classification outline of the animal kingdom given on pages 987–994. A wide acquaintance with many different plant and animal forms and a wide knowledge of how they carry on their lives is the best possible equipment for testing the ideas and principles that biologists discuss or accept. As has been suggested, it will advance you greatly in your biological understanding if you will regard the different plants and animals that you study, not as isolated species, but as representatives of their larger groups. You should be able to see that the characteristic features of each group are the embodiment of a plan for meeting life problems in a particular way.

Of all things on earth, life is indeed the most wonderful. If our ideas of it are at all correct, it has endured the hardships of hundreds of millions of years. It has adapted itself to all the conditions of a changing environment. It has triumphantly survived in spite of all the difficulties an unstable earth has imposed. In doing this it has constantly varied and expressed itself in countless new ways. In future it will doubtless go on to new forms and heights we do not yet know. The plants and animals of today are no more fixed and final than were those or the past.

UNIT COMPREHENSION TEST

- A. Describe Planaria and its life habits. What is the body plan of Planaria? Describe the nervous system; the digestive system. How are wastes excreted? How does Planaria reproduce? What happens if a planarian is cut in several pieces?
- B. What are the characteristics of the roundworms? Describe Ascaris and its life history. What other roundworms cause human disease? Describe trichina and its life history. What are some other roundworm parasites?
- C. What is the earthworm body plan? What is a nephridium? Into what distinct parts is the alimentary canal divided? What does the earthworm eat? How does it make its burrow? Describe the circulatory system; the nervous system. How does an earthworm crawl? In what are the eggs deposited? Why are earthworms important animals?
- D. What are the characteristics of the arthropods? Why do arthropods moult? What is meant by metamorphosis in an animal? How does a millipede or a centipede differ from an earthworm? Why is Peripatus interesting?
- E. What is meant by incomplete and complete metamorphosis in an insect? What are the four stages in the life of insects that have a complete metamorphosis? What are the divisions of the insect body? How many legs has an insect? How many wings? Describe the respiratory system of an insect. What is a spiracle? Describe the nervous system and sense organs of insects. How do insects reproduce? What are the advantages of the insect plan?
- F. To what order of insects does the grasshopper belong? What two groups of grasshoppers are there? What do they eat? What parasitic enemies do they have? How does the grasshopper reproduce? Where do the grasshoppers that appear in swarms breed? What is the life history of the housefly? What are the best means of controlling flies? Why is the mosquito important? What is its life history? How are mosquitoes controlled? Describe the life and activities of the wasps.
- G. What are some important predatory insects? What other natural checks are there on insects? How do the gardeners and orchardists protect crops from insects? What new methods of insect control may become important?
- H. What animals besides the spiders are included in the order Arachnida? How do spiders capture their prey? What types of webs do they weave? What are the divisions of a spider's body? How does a spider spin its web? Where are the eggs laid? Describe the scorpions.

SUGGESTED ACTIVITIES AND APPLICATIONS

1. Place a planarian in a watch glass of water. Observe its general body form and, if it is alive, its movements. Examine it with the low power of the microscope. The much-folded structure within is the intestine. Try to see the proboscis. Make a sketch of the animal. How does Planaria differ in body plan from Hydra? If you have a live specimen, cut it in two, leave it in water, and watch results.

2. Examine prepared slides of hookworm and trichina. In your notebook make charts showing the life histories of these worms and also of Ascaris.

3. Examine an earthworm, noting the clitellum. Feel along the sides of the body for the setae. Observe the way the worm crawls.

Watch the back of the worm for the pulsing of the dorsal vessel. This can be seen best on a large worm that has been kept between moist filter papers until the alimentary canal is empty and the worm has become more transparent.

With a pair of fine scissors open a preserved worm along the back and identify parts shown in the illustrations on pages 323–325. The dissection can best be done under water. If you do not have a "dissecting pan," make one by pouring a layer of melted wax or paraffin into a shallow baking pan (or plate). Use pins to hold the body walls spread out as you work.

- 4. Fill a pot, or other vessel that has drainage, with rich earth, pressing the earth down. Introduce several large earthworms. When they have buried themselves, smooth the surface of the earth and sprinkle a thin layer of sand over it. Observe the burying of the sand. Water if the soil becomes dry.
- 5. Let members of the class bring in millipedes; centipedes; silver fish or other primitive insects. In what two important ways do all these differ from the earthworm?
- 6. If possible, secure insect material that will show incomplete and complete metamorphosis.
- 7. Make a study of the anatomy of the grasshopper. Look for the spiracles. Peel the outer layer from the eye of a grasshopper (or other insect) and examine it under the microscope.
- 8. Examine the feet and tongue of a fly with a low-power microscope; raise mosquitoes in an aquarium and watch their development; observe the behavior of wasps.
- 9. Keep in your home or in the schoolroom different kinds of insects in captivity.

IMPORTANT INSECT ORDERS

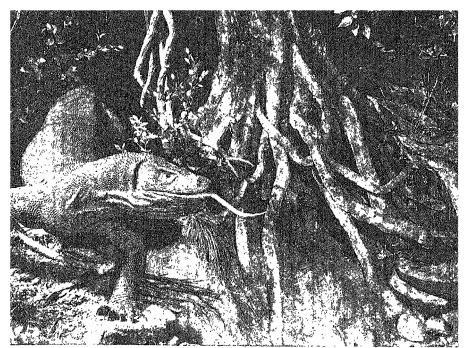
Insects are usually classified in nineteen orders. Among the more important and familiar orders are the following:

- 1. Aptera (α p'ter-a; Greek α , without, + pteron, wing). Without wings. Examples: springtails, silver fish or fish moth (page 329), and snow fleas.
- 2. Odonata (ō'do-na'ta; Greek odous, tooth). Four long membranous wings. Dragonflies and damsel flies.
- 3. Orthoptera (ŏr-thop'ter-a; Greek orthos, straight, + pteron, wing). Four wings. Outer ones leathery. Crickets, grass-hoppers, cockroaches, praying mantis, walking stick.
- 4. Hemiptera (he-mip'ter-a; Greek hemi, half, + pteron, wing). The bugs. Sucking insects. Plant lice, scale insects, squash bug, giant water bug, chinch bug, bedbug, stinkbugs. The cicadas belong in this order.
- 5. Neuroptera (nyu-rŏp'ter-a; Greek neuron, a nerve, + pteron, wing). Delicate membranous wings. Ant lions, aphis lions, dobson flies.
- 6. Lepidoptera (lĕp'i-dop'ter-a; Greek lepis, a scale, + pteron, wing). Wings covered with scales. Butterflies and moths.
- Diptera (dĭp'ter-a; Greek dis, doubly, + pteron, wing). Two wings, sucking mouth parts. Flies and mosquitoes.
- 8. Siphonaptera (sī'fo-nāp'ter-a; Greek siphon, siphon, + apteros, wingless). Degenerate insects without wings. Sucking mouth parts, complete metamorphosis. Fleas.
- 9. Coleoptera (kŏ'le-ŏp'ter-a; Greek koleos, sheath, + pteron, wing). Four wings, inner pair membranous and outer pair hard and shelly. Weevils and beetles.
- Hymenoptera (hī'mĕn-ŏp'tĕr-a; Greek hymen, membrane, + pteron, wing). Four membranous wings. Sawflies, gallflies, ichneumon flies, ants, wasps, bees.
- 10. Determine the orders to which any insects that come to the attention of the class belong. Learn the family, genus, and species of the specimen if this is possible.
- 11. Observe spiders. Identify as nearly as you can the ones you observe.

References

COMSTOCK, JOHN H. The Spider Book. Doubleday, Doran & Co., Inc., New York; 1914.

LUTZ, FRANK E. The Field Book of Insects. G. P. Putnam's Sons, New York; 1935.



American Museum of Natural History

UNIT 9 THE COLD-BLOODED VERTEBRATES

Life develops along a new line. An internal jointed skeleton makes possible a great increase in size.

"Though vertebrates as adults are rather diverse in structure and habits, they are all built according to the same fundamental plan and pass through similar stages in development."

A. S. Pearse

ORIGIN AND CHARACTERISTICS OF THE VERTEBRATES

QUESTION FOR CLASS DISCUSSION

What characteristics of the vertebrates have made them the dominant animals of both water and land?

EUGLENA and similar forms suggest a relationship between plants and animals. Peripatus indicates a connection between arthropods and segmented worms. Several groups of small marine animals that are included with the vertebrates in Phylum Chordata break the sharpness with which the vertebrates are set off from the invertebrate groups. Pictures of some of these humble relatives of the vertebrates are shown on page 836.

In form and appearance they are very different from each other, but they are all alike in two ways. All of them have a rod of fibrous, rubbery tissue, called the notochord, buried in the back. All of them have a nerve cord along the back of the body instead of along the ventral side as in the segmented worms and arthropods. The vertebrate embryo at one stage of its development has an unjointed notochord and the vertebrates are supposed to be descended from some little animal that had a dorsal nerve cord and a rod of stiffening and supporting tissue in its back. In the adult vertebrate the notochord is developed into the jointed backbone or spinal column which is the central feature of the vertebrate skeleton. Each segment of the spinal column is called a vertebra (plural vertebrae). The vertebrates are the animals that have a chain of vertebrae in the back.

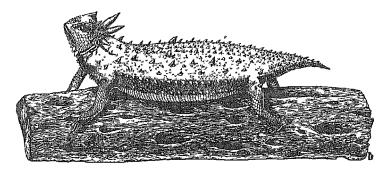
One of the chief characteristics of the vertebrate body is the strong jointed skeleton, which instead of being on the outside of the body as in the arthropods is buried within. The internal jointed skeleton gives both a freedom of motion and a strength and firmness of support to the body that allows the vertebrates to

grow to a size far beyond that of any other animals. There are small vertebrates like minnows and mice, but generally speaking the vertebrates are large animals. No invertebrate can even be compared in weight and bulk with the dinosaurs and great mammals of the land and with the sharks and whales of the sea.

In their general body organization the vertebrates are very complex. Their internal organs and glands are more highly developed than those of other animals. They have a far more elaborate circulatory system. They have brains that are beyond comparison the most intricate in the animal kingdom. They have an unrivaled equipment of sense organs that put their brains in contact with the outside world. In taking up the vertebrates we are beginning the study of the group whose members are the dominant animals of the world today.

Problems in Unit 9

- 1 What are the general characteristics of the vertebrate body?
- 2 What are the characteristic features and special adaptations of the fishes?
- 3 What are the groups and characteristics of the amphibians?
- 4 What are the groups and characteristics of living reptiles?



The horned toad. Its body is of the typical vertebrate form.

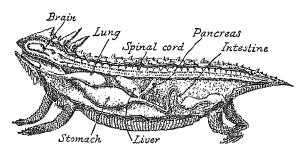
PROBLEM ONE

What Are the General Characteristics of the Vertebrate Body?

The vertebrates are animals of water, land, and air. They are so diverse in form and structure that we are often impressed by the differences rather than by the resemblances among them. Yet, as we shall see, the bodies of all vertebrates are constructed according to the same general plan. The comparative anatomist can trace a common pattern through them all.

Vertebrate body plan. The typical vertebrate body consists of a head, a trunk, a tail, and two pairs of limbs. There is a jointed skeleton. In the body there is a dorsal cavity and a ventral cavity. The dorsal cavity runs through the spinal column and at the head expands inside the cranium. This cavity contains the spinal cord and brain. The ventral cavity is large and contains a great assortment of organs — the heart, the digestive and excretory organs, and in the air-breathing vertebrates the lungs. On pages 467 and 479 the cavities and internal organs of the human body are shown.

A statement that may be surprising to you is that the vertebrate body is segmented. This is shown by the division of the spinal column into segments, or vertebrae; by the pair of nerves that come off from the spinal cord to each of the segments; and usually by the attachment of a pair of ribs to each vertebra in at



Section through the body of a horned toad (diagrammatic). The lungs, liver, pancreas, and kidneys are formed from infoldings of the endoderm.

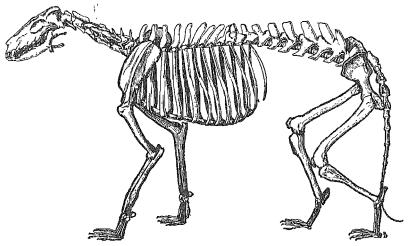
least a part of the body. In the fish the segmentation can easily be seen in the muscles. In the mammals there are short muscles that run from vertebra to vertebra and from rib to rib; but these short, segmented muscles are concealed by a covering of fat and by long muscles that move the limbs.

The tail is important as a swimming organ in the water vertebrates, and is powerfully muscled. Among the land forms it has many modifications, and in the adult frog all trace of it is lost. The general body form of the first vertebrates was probably somewhat like that of the lamprey shown on page 837.

Development of vertebrate body. The illustration on page 361 shows in a diagrammatic way the plan of early vertebrate development. The endoderm is folded in to form an alimentary canal, which extends through the body. The lining of the canal (also the lining of the nose and air passages) is kept moist with mucus and is called mucous membrane. The surface layer of a mucous membrane is called the epithelium (ĕp'I-thē'lĭ-um). The lungs, liver, and pancreas are developed from infoldings, or pockets, of the endodermal layer.

The ectoderm forms the outer layer of the skin. This is called the *epidermis*. The spinal cord and other parts of the nervous system are developed from a roll of epidermis which in the early stage of the embryo is folded in and buried in the back (page 491). Many of the germs that grow in the skin and cause skin infections

also cause diseases of the nervous system. This is explained by the fact that the skin and the nervous system develop from the same body layer. The spinal cord and brain lie in the dorsal



Skeleton of an Irish wolfhound. All the vertebrates have a jointed internal skeleton, the central feature of which is the backbone.

cavity which is formed by the bones of the spinal column and head growing over and enclosing the nerve tissue.

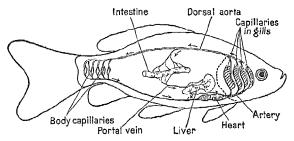
The mesoderm is a thick middle layer from which are fashioned the skeleton, the muscles, and the heart and the blood vessels. The connective tissue and fatty tissue of the body also arise from this layer.

Skeleton and muscles. The skeleton and the muscles attached to it make up the *locomotor system*. The skeleton supports the different body parts and provides a system of levers by which the body can be moved. The muscles by their contraction furnish the power for movement. Usually a muscle is so attached that it stretches across a joint. The movement is caused in the manner indicated on page 470.

The skeleton consists of two parts, the axial skeleton and the appendicular skeleton. The axial skeleton is the skeleton of the trunk, head, and tail—the skeleton of the axis of the body. The appendicular skeleton is composed of the bones of the limbs and

of the bones of the pelvis and shoulder, which join the limbs to the trunk. It is the skeleton of the appendages. In addition to supporting the body and making movement possible, the axial skeleton protects the delicate organs of the body. The spinal column and cranium shield the spinal cord and brain, and the bones of the trunk form a protection for the soft inner body parts.

Circulatory system. All the vertebrates have a circulatory system. They are large and active animals, and they



Circulatory system of a fish. Trace the circulation from the heart back to the heart again.

must have a way of distributing food and oxygen through the body and of removing cell wastes. The vertebrate circulatory system consists of a muscular heart and a set of vessels, which carry the blood through all the tissues and bring it back to the heart again. In the gills or lungs the blood takes in oxygen and gives off carbon dioxide. In among the body tissues it supplies oxygen and food to the cells and takes up carbon dioxide and other cell wastes. The vessels that carry the blood away from the heart are called arteries. The ones that bring it back to the heart are called veins. The blood gets from the arteries to the veins through microscopically fine vessels that are called capillaries.

In the different groups of vertebrates the circulatory scheme differs, becoming more complex in the higher forms. A diagram of the circulatory system of the fish is shown above. That of a mammal will be found on page 478.

Glands of vertebrate body. In accordance with the plan of specializing the tissues, the vertebrates have a great

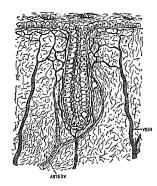


Diagram of the structure of a simple gland.

system of glands. These manufacture chemical substances needed by the body or they excrete materials from the body. Lower forms like the worms and insects also have glands, but the vertebrates have carried gland development to a new height. Their glands may be divided into two classes, those with ducts and those that have no ducts.

Perhaps the most important of the glands that have ducts are those of the alimentary canal, which manufacture

the enzymes that digest the food. Others that might be mentioned are the sweat glands; the mucous glands in mucous membranes and in the skins of frogs; the poison glands of snakes; the oil glands at the bases of the hairs in mammals; and the scent glands that many animals have. The kidneys might also be looked on as belonging in the list of glands.

Some of the glands with ducts are very simple and some, like the salivary glands, pancreas, and liver, are very complex. The structure of a simple gland similar to those found in the wall of the intestine is shown in the illustration above. In it the cells are arranged in the form of a hollow tube. On one side the gland cells take in liquid and other materials from the blood. On the other side they give off a liquid into the hollow in the center of the gland. The liquid that flows out of the mouth of a gland is called the *secretion* of the gland. Usually a gland builds some particular substance that the body needs and adds it to the secretion.

The glands that lack ducts are called the *endocrine* glands. They manufacture and release into the blood chemical substances called *hormones* that assist in the regulation of the body processes. The vertebrate body is highly complex, and the hormones help to keep all its organs and parts working together as one harmonious whole. The illustration on page 503 shows the location of the endocrine glands in the mammalian body. In a later unit we shall study the special functions of some of these glands in some detail.

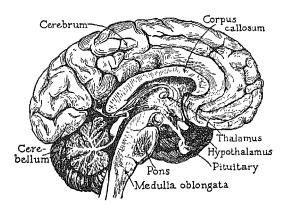
The nervous system. The vertebrates have specialized in the development of a nervous system. The nerve cord has a swelling (corresponding to a ganglion in the earthworm) where



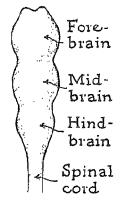
Diagram showing notochord and nerve cord in Amphioxus. In this little pro-vertebrate there is no expansion of the nerve cord at the front end into a brain.

each pair of nerves comes out, and to a considerable degree each segment of the nervous system governs its own body part.

At the head end there is a brain (in most vertebrates highly developed) that regulates and coördinates the actions of all the body. The brain has been made by fusing the ganglia at the head end of the nerve cord and adding certain outgrowths to them. In the mammals, twelve pairs of nerves (cranial nerves) come off from the lower side of the brain and from this it is inferred that the first twelve segments of the nervous system have



Longitudinal section through the center of the human brain. The lower midbrain (thalamus and hypothalamus) are the seat of the instincts and emotions; consciousness and thought are located in the cerebrum.



The three primary divisions of the vertebrate brain.

been fused in the mammalian brain. In the trunk the vertebrates show a segmented structure in the skeleton, nerves, and muscles, but in the head the segmentation has been lost.

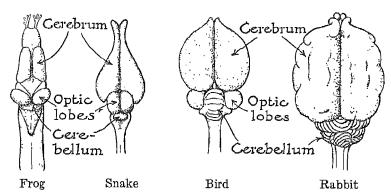
The vertebrate brain. Even the most primitive of the living vertebrates are in brain development advanced far beyond the Amphioxus state. In them the front part of the cord is expanded to form a primitive brain with three divisions, as shown in the illustration. The brain of a higher vertebrate at an early stage is of this simple type, but as the organism grows the brain increases greatly in complexity.

Out of the forebrain a pair of growths called the *cerebral* (sĕr'e-bral) *hemispheres* push up. These together make up the *cerebrum*, which in the higher vertebrates forms by far the larger part of the brain mass.

The midbrain gives rise to a pair of optic lobes. In each of these, where the nerve impulses from the optic nerves are received, there is a mass of nerve cells ("gray matter") that is called the optic thalamus (plural thalami; thăl'a-mī). The lower part of the midbrain, down below the optic thalami, is called the hypothalamus (Greek hypo, below, + thalamus). It is in the lower midbrain that the emotions and instincts are believed to have their seat.

From the hindbrain there is an outgrowth called the *cerebellum*, which aids in muscular control. In the higher forms the cerebellum and *medulla oblongata* (me-dŭl'a ŏb'lŏng-gā'ta) taken together make up the hindbrain.

The surface of the cerebrum in the higher vertebrates is thrown into folds or wrinkles that are called *convolutions*. The surface material is a layer of nerve cells (gray matter). This is called the *cerebral cortex*, and it is usually accepted that it is the seat of consciousness and thought. In the development of intellectual functions of the brain the vertebrates far excel all other animals.



As we ascend in the classes of the vertebrates, the brain and especially the cerebrum greatly increase in size.

Some of the insects have elaborate instincts, but only a shadow of "intelligence" is found below the vertebrate group. In connection with a study of the mammalian body we shall take up the vertebrate nervous system in some detail.

Vertebrate sense organs. The vertebrates have a battery of sense organs that are incomparably the best in the animal world. They have eyes that, like a camera, form images of objects and focus for seeing near and distant objects. They have ears for hearing and an olfactory organ for smelling. They have specialized nerve endings of taste and touch, and other nerve endings that give sensations of temperature or pain. These sense organs, like the nervous system, are developed from the ectoderm. They are outposts of the nervous system where information of the outside world is gathered and relayed to the brain.

The size and the complex organization of the vertebrate body of necessity give rise to new difficulties in living. The vertebrates face more complex problems than the simpler animal forms. They have, however, met these problems in a very successful manner. The fishes rule the water, the birds are supreme in the air, the mammals are masters of the land.

PROBLEM TWO

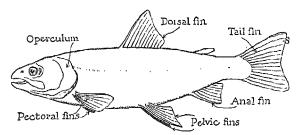
What Are the Characteristic Features and Special Adaptations of the Fishes?

All the water-living vertebrates are commonly thought of as fishes, but scientifically they are divided into three classes. These are (1) the Cyclostomata (hagfishes and lampreys), (2) the Elasmobranchii (sharks and rays), and (3) the Pisces, or true fishes (page 992).

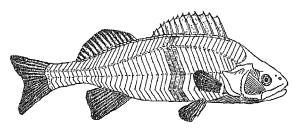
In the cyclostomes the notochord becomes jointed, but even in the adult the vertebrae are composed of fibrous material. There are no jaws and no paired fins corresponding to the limbs of higher vertebrates. The elasmobranchs have jaws and paired fins, but in them the skeleton is made of cartilage. The true fishes are the first group with skeletons made of bone.

Examination of a fish. If you will examine a typical fish (as a goldfish or perch) you will see a horny flap on the side of the head. This is the *operculum*, or gill cover. Its function is to protect the gills, which are soft structures made up of hundreds of little finger-like filaments. Blood circulates through these filaments and the fish obtains oxygen and gives off carbon dioxide by taking water into its mouth and passing it back over the gills and out through the *gill slits*. The gills are delicate structures and the operculum protects them from injury when the fish swims through vegetation, fights, or struggles with its prey.

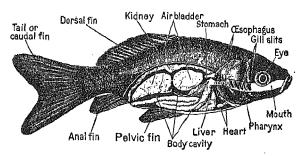
Typically a fish has in addition to its other fins two pairs of fins on the sides of its body. These are called the *pectoral* and *pelvic fins*. They correspond to the two pairs of limbs that other vertebrates have. Watch a fish swim and you will see that it drives itself through the water with its tail and by curving its body, and that the fins are used mainly for balancing. The speed of some fishes is very great. An Atlantic sailfish has a record of 100 yards in 3 seconds, which is about twice as fast as a horse or a deer can run on the land. Many fishes are swifter than any land animal.



External view of the body of a fish. The pectoral and pelvic fins correspond to the two pairs of limbs found in higher vertebrates.



Like other vertebrates, the fish is segmented. The segmentation can be seen not only in the spinal column and nervous system but also in the muscles.



Some of the principal organs of the goldfish. The reproductive organs which are prominent in the breeding season are not shown.

Internal organs of a fish. The figure on the preceding page shows some of the internal organs of a goldfish. There is a digestive tract, liver, kidneys, reproductive organs (ovaries or testes), and a heart and blood vessels. The drawing on page 373 shows the circulatory scheme. The blood is pumped forward from the heart, passes through the gills, then goes through the body and back to the heart.

An interesting structure found only in the true fishes (not in sharks, rays, or lamprey eels) is the air bladder, or swim bladder, which helps them to rise and sink in the water. If a fish wishes to go down it absorbs a part of the air in the bladder into the blood, which brings the bladder to smaller volume, makes the fish heavier for its size, and causes it to sink. If it wishes to come to the surface it secretes air into the bladder, which expands and makes the fish more buoyant.

Reproduction in fishes. The breeding habits of fishes vary greatly. A few species guard the eggs and usually it is the males that assume this task. The male stickleback builds a neat little nest which he hangs to weeds or other vegetation. Then he



persuades a female to deposit eggs in the nest and repeats this with other females until the nest is full. The male hovers over the eggs until they hatch and courageously fights with anything that comes near. The male of one kind of catfish carries the eggs about in his mouth until they hatch,

The nest of the little stickleback. The nest is built by the male and the eggs and young are valiantly guarded by him. THE FISHES

going without eating for three months as he does The male of the sea. horse carries the eggs in a pouch on the abdominal wall.

In general, however. the fishes follow the plan of starting many young in life and leaving them to their fate. The female perch lavs as many as 100,000 eggs in strings in shallow water and she may even eat her own eggs and young. The codfish lays 9,000,000 transparent eggs, which float without care on the surface of the sea. Adult fishes, turtles, crustacea, and the larvae of insects prey on the eggs and young of fishes and a high percentage of them

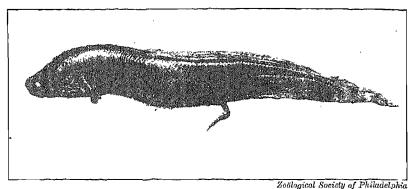


James Sawders

Salmon leaping a waterfall. Many fishes make long migrations to start their offspring in the waters inhabited by their ancestors. Some of the salmon travel 2000 miles upstream to reach their breeding grounds.

are destroyed. In some fish hatcheries trout are now raised to a size suitable for anglers to take before they are placed in streams, because when they are released as fingerlings too few survive.

Migrations of fishes. In connection with their breeding some kinds of fish make long migrations. Fresh-water eels go down to the ocean to lay their eggs and the young pass their early life far out in the open sea. On the other hand the salmon, shad, and many other fishes spend most of their lives in the sea and ascend rivers and smaller streams to spawn. The young are hatched in fresh water and only after they are started in life do they go down to the sea.



Zoological Society of Philadelphia

Australian lungfish, which has a true functioning lung. It lives in muddy water and occasionally comes to the surface for air.

It is thought that these migrations point back to ancestral conditions. The salmon and other ocean fish that spawn in fresh water are believed to have been originally fresh-water forms that went down to the mouths of the rivers and gradually worked their way out to sea. The eels, on the other hand, are thought to be descended from an old-time family of ocean dwellers. Each species returns to its ancestral home to start its young. It is interesting to note that although the breeding grounds of the European and American eels overlap in the Atlantic, the members of each species turn unerringly to their own continent when the time for the journey to fresh water comes. The young of the two species at places live together in the ocean, but no European eel has ever been found in an American stream and no American eel in a European one.

We think of the sea as being the home of the fishes, but from early in their history they have lived also in streams and freshwater lakes and swamps. Indeed, so abundant are the early fishes in fresh waters that some scientists have thought they originated there. However that may be, the fishes are ancient inhabitants of both salt and fresh water, and doubtless some of the modern kinds originated in lakes and streams and others in the sea.

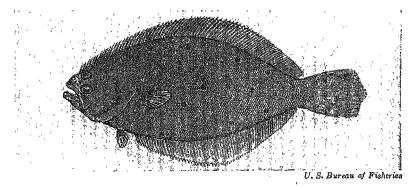
The lungfishes. The African lungfish has already been mentioned (page 212). It is a member of a group of ancient fishes

THE FISHES 383

which long ago put the air bladder to a new use. They developed a duct that connected it with the throat and used the bladder as a simple lung. Only a few species of these old fishes survive. Besides the one found in Africa there are two in South America and one in Australia. They are adapted to stagnant water or to a climate in which there are alternating seasons of heavy rainfall and drought. One of the South American species, like its African relative, estivates in the mud. The Australian species lives in stagnant water and frequently comes to the surface for air.

Many of the fossil fishes found in ancient rocks are similar in form to the lungfishes. It is supposed that the amphibia developed from one of them that found its lung good enough to let it leave the water and venture out on land.

Adaptability of fishes. The most interesting thing about fishes is their wonderful adaptation to the varying conditions of water life. There are 13,000 different kinds of them, which means that the group shows a great variability — a tendency in the offspring to be different from their parents and for the development of new kinds rather than for a family of them to breed on and on without change. This plasticity of the fish protoplasm has given us little fishes and big ones. In the sea it has produced both free-swimming kinds and queer flattened species for bottom life. It



The flounder, a fish adapted for life on the ocean floor. Its flattened form and dull coloring make it inconspicuous as it rests on the sand or mud. It lies on its side, and during its development the eye on the lower side works around to the upper surface of the head.

has developed flying kinds that leave the water and gliding on their wide fins sail an eighth of a mile through the air. There are kinds that can live in the hot summer water of a small pond, swim actively about under the ice, and endure being frozen in the ice. Other kinds fitted out with phosphorescent lamps live miles below the sunlight zone amidst the awful darkness and stillness and cold of the ocean floor. Visit an aquarium or take up a book on fishes and you will find yourself fascinated and bewildered by the seemingly infinite variety of kinds.

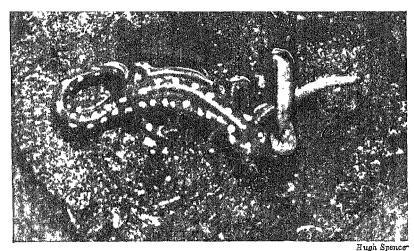
We must count the fishes as one of the most successful of the animal groups. Time has not dimmed the ardor of the fish stock for life nor has age taken away their adaptability to changing conditions. The reptiles took the land and lost it. Hundreds of millions of years ago the fishes were crowned as the rulers of the waters and there has risen no challenger for their wet throne.

PROBLEM THREE

What Are the Groups and Characteristics of the Amphibians?

The amphibians are the animals that live both in water and on land. The two principal divisions of them are the frogs and toads, which in adult life lose their tails, and the salamander tribe, which keep their tails. In addition there are a few tropical species of little limbless, worm-like or snake-like amphibia that live in moist ground.

The salamanders. Strictly speaking, only one family of the tailed amphibians are salamanders, but the word is popularly used to include all the near relatives of this family and we shall use it in its wider sense. The common ones are little lizard-like animals only a few inches in length. They have moist, slimy skins and no nails on their toes. In the early stages, and in some species all through life, there are little tree-like gills attached to the sides of the neck. The limbs are weak and walking is slow. Salamanders live under stones or logs or in other moist places, and nearly all of them go to the water to lay their eggs.

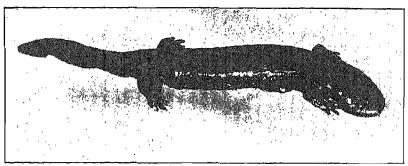


Spotted salamander attacking an earthworm.

Kinds of salamanders. The tiger salamander, Ambystoma (ăm-bĭs'to-ma), is common over the central and eastern part of the United States. It is about 8 inches long, has a stout body, and in color is dark brown blotched with yellow.

Another species, the red-backed salamander, *Plethodon* (plĕth'o-dŏn), does not enter the water even to breed, but lays its eggs in pockets in damp places under logs and stones and guards them until they hatch. The young have two rows of red dots along the back. In the adult these change to a red band or stripe.

One family of salamanders are called *newts* and there is one species of these in our Northeastern states and one in the Western states. The Eastern one lives for about three years as a green little water animal. Then it takes to the land and becomes the "red eft," which is bright orange in color with red spots. After a time it returns to the water to breed, and while there it again becomes green in color and leads an entirely aquatic life.



Zoological Society of Philadelphia

The hellbender, a heavy-bodied relative of the true salamanders. A Japanese species closely related to the hellbender reaches a length of 5 feet.

The Congo snake is a slender species of salamander that is 2 or 3 feet long. It has very small limbs (not more than an inch long) and is found in the ditches and marshes of our South. The hell-bender is a heavier species that reaches 18 or 20 inches in length. The mud puppy or water dog, *Necturus* (něk-tū'rus), of the



The mud

Salamander tadpole. The bushy gills are on the sides of the neck. puppy retains its gills throughout its entire life.

streams and lakes north and west of the Alleghenies, and the siren, or mud eel, of the South, are relatives of the true salamanders.

Frogs and toads. The frogs and toads make up the other principal branch of the amphibian tree. They begin life as legless tadpoles with gills and go through a metamorphosis which changes them into land animals with lungs and four strong limbs. It is believed that the air-breathing vertebrates originated by water forms' developing lungs and coming out on the land. The frogs and toads prove that this can be done. By watching one of them develop we can see before our eyes a water animal changing into one fitted for land life.

Tadpoles live on algae, vegetable scum which they scrape from weeds and other objects, or other vegetation. In the adult stage the frogs and toads eat animal food. In metamorphosis the intestine shortens to about one seventh the length it had in the tadpole stage. The largest of our frogs is the bullfrog, which may have a body length of 8 inches. It is a voracious eater, feeding on fishes, crayfishes, other frogs, or even young ducklings. Its legs are prized for food and about 250,000 pounds of them are sold in the markets of our country each year.

In the winter toads burrow into the earth below the frost line: frogs go down into the mud at the bottom of ponds and lie motionless and dormant until they are revived by the warmth of spring.



The leopard frog. This attractive spotted frog sometimes lives in meadows and bottom-land pastures at considerable distances from water. Except on the Pacific coast it is the commonest of all our frogs.

During the hibernation the life fires burn low, being kept up with fuel that has been stored in the body and oxygen absorbed through the skin.

The amphibians are now the least important of the vertebrate groups and it is not probable that they ever held any large place in the life scheme. They are interesting chiefly because of the information they give us about how the higher vertebrates may have made the transition from the water to the land. The old-time amphibians described on page 168 were the first land vertebrates and the first vertebrates with walking limbs.

PROBLEM FOUR

What Are the Groups and Characteristics of Living Reptiles?

Reptiles are cold-blooded, air-breathing vertebrates with dry, scaly skins. The living ones are the surviving twigs of a great tree that is dead and gone; and these twigs came from branches that were far apart on the original tree. The different groups therefore differ greatly from each other, so that it is difficult to give any description of the class of reptiles as a whole. surviving reptile assemblage consists of the lizards, snakes, crocodiles, turtles, and a lizard-like reptile of New Zealand that is related to the dinosaurs. Turtles, crocodiles, and some snakes and lizards live in or about the water, but all reptiles breathe by lungs. All of them come to the land to lay their eggs. Even in the early stages of life they have no gills. The snakes and some lizards have lost their limbs and some turtles have only flippers, but where the toes are retained they are equipped with nails. The reptiles lay rather large eggs with tough membranous cover-In some snakes the eggs are retained in the body of the mother until they hatch, so that the young are born alive. The turtles have horny, shearing beaks; the other reptiles have rows of peg-like teeth.



Fish and Wildlife Service

The Gila monster of our Southwestern dry regions. It is one of two known species of poisonous lizards and the only poisonous lizard of the United States. Its poison glands are in the lower jaw. When struggling with its prey, it throws itself on its back so that the poison may drain down into the wound.

THE LIZARDS

There are about 1600 known species of lizards. Most of them are small, but some reach a considerable size. Some are vegetarians, but most of them are flesh eaters. The smaller carnivorous ones feed on insects and worms and the larger ones add to their diet animals of greater size. They have four limbs and most of them are swift in their movements.

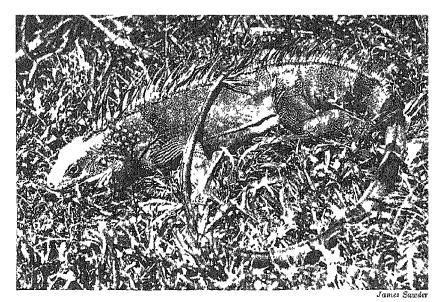
Iguanas and monitors. The iguanas are found in the tropics of the New World, the monitors in the tropics of the Old World. The iguanas of Central and South America may be 6 feet long. Those of the Galapagos Islands off the coast of Ecuador feed on seaweed. They go into the water for their food, and have the tail flattened from side to side, which adapts

them for swimming.

The monitors of Africa, India, Australia, and the Pacific Islands run swiftly and look much like snakes equipped with short legs. They may be 7, 8, or even 9 feet long. One species, the rare dragon of Komodo (one of the islands of the East Indies), may grow to a length of 12 feet and may weigh 200 pounds. It kills deer and pigs as well as smaller animals.



The American chameleon lizard. It is a small lizard of our Southern states that changes its color. The true chameleons are flattened from side to side and are found only in the Old World.



An iguana of tropical America. Some of the iguanas are 6 feet long. In place they are very abundant.

Common lizards of United States. Many of the swift-running little lizards of the desert parts of our Southwestern and Western states belong to a group popularly called "swifts," and certain of the small lizards of the Central and Eastern states are called "skinks." The five-lined skink has five stripes down the back, but as the animal gets older the stripes become dull and in the male disappear. The young of this species have blue tails and the old males have red heads. The young, the adult males, and the females of this species may easily be mistaken for lizards of three different kinds.

The "glass snake" of our Central states is a limbless lizard with a very short body and a long, brittle tail. The tail is often broken off and left behind with a foe while the head part makes its escape. The horned toad and the Gila (hē'la) monster are well-known lizards of our arid states.

THE SNAKES

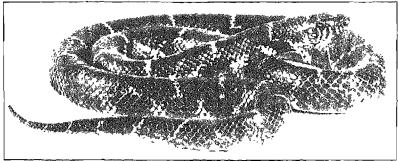
The snakes are limbless, but it is supposed that they are descended from slender reptile forms that once had limbs. The python and a few other species have a pelvic girdle and a pair of

spur-like appendages which are vestiges of the hind limbs. There are about 1600 species of snakes, 111 of which are found in the United States. Snakes vary greatly in size. Some burrowing kinds are smaller than our earthworm. Pythons may be 30 feet long and anacondas may weigh 300 pounds.

The snake body. The body of a snake is typically long and slim. The number of vertebrae is very great — in a boa constrictor there may be four hundred. Ribs begin on the second vertebra and continue back to the beginning of the tail. The ribs have muscles attached to them, and across the lower side of a snake's body the skin is thrown into overlapping horny plates called *scutes*. In crawling the scutes take hold on the ground. A pair of ribs is attached to each one and the animal moves by using its ribs as legs and the scutes as feet. A black snake has a speed of about 10 or 12 miles an hour.

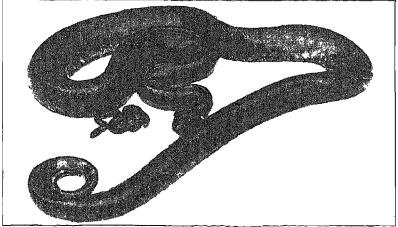
All the snakes are carnivorous and all swallow their prey without chewing. The upper and lower jaws are not hinged together, an arrangement which allows them to be stretched apart and permits large animals to be swallowed whole. The opening of the trachea is far forward in the floor of the mouth so that the snake can still breathe while swallowing an animal four or five times the diameter of its own neck. In the snakes one lung fails to develop and the other extends far back in the slender body. The eyelids are fused over the eye, but there is a transparent part through which the animal can see. At least once a year a snake sheds its horny skin and for a time before it does this its sight is very poor. Externally a snake differs from a lizard in having no limbs, in not being able to close its eyes, in having the jaws separate, and in having no tympanic membrane ("eardrum") on the side of the head.

Our non-poisonous snakes. Among the harmless snakes of our country there is a great variety and they live and feed in very different ways. Some live on insects, worms, mice, and toads. Others live in and about the water and subsist on frogs and fish. The king snakes kill their prey by squeezing it. They are among the best friends of the farmer. One of the king



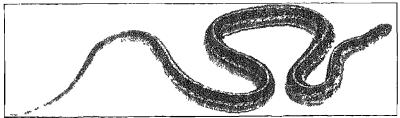
Fish and Wildlife Service

In our country the king snakes are the rulers of the snake world. They are immune to the venom of poisonous species and without hesitation attack and kill them. King snakes are among the farmer's best friends.



New York Zo logical Society

An 18-foot anaconda and its young. The anacondas are inhabitants of tropical America and may attain a length of 25 feet.



Pash and Wildlife Service

The garter snakes are slender and have yellow stripes (usually three) down the back. The young are born alive. They are the commonest of our snakes and are entirely harmless.

snakes about 3 feet long (called the "milk snake") is a relentless foe of mice and rats. A larger species is a determined killer of poisonous snakes. It is immune to their venom and attacks without hesitation a rattlesnake, copperhead, or water moccasin on sight. A 6-foot king snake is more than a match for any other snake in North America and deserves its title of "king." There are more of the harmless snakes than is generally supposed, for they live hidden away in weeds and grass where they are not seen.

Poisonous snakes of United States. Of the poisonous snakes there are five kinds in our country. One of these is the small but dangerous coral snake of the South, which is marked with rings of scarlet and blue-black separated by rings of yellow about its body. Another is a small Southern snake, not very dangerous to man, that has poisonous back teeth and uses its venom to kill animals as it holds them in its mouth.

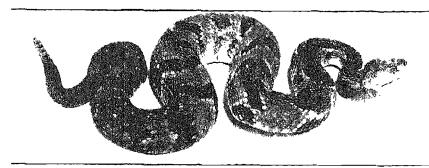
The other three venomous kinds are the copperhead, water moccasin, and rattlesnake. All of these have thick bodies, wide heads, and slender necks. A pit in the side of the head between the nostril and eye gives these snakes the common name of "pit viper." They have in the upper jaw two sharp fangs with poison glands at the base, and when they strike the venom is injected into the wound through hollows or grooves in the fangs. The fangs are attached to a hinged bony plate at the base and when not in use they lie turned back flat, along the roof of the mouth. The poisonous snakes use their fangs not only to defend themselves but also to kill their prey. Rabbits are the favorite food of some species of rattlesnakes. The snakes capture them by striking them when they come within reach.

The copperhead is found from central New England west to central Illinois and Kansas, and south to Florida and Texas. In

The pictures on the opposite page show the three kinds of pit vipers found in our country. The copperhead (left above) is $2\frac{1}{2}$ or 3 feet long. The water moccasin of the Southern swamps (upper right) is much larger. The center picture is that of a timber rattlesnake, and below a Florida rattler is shown striking a rabbit. Note the heavy bodies, narrow necks, and wide triangular heads of these snakes. (Two lower photographs from Fish and Wildlife Service.)



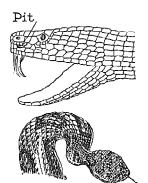
E R Deats





the North it is usually in or near forests. In the South it prefers the open fields. The average length of a full-grown specimen is about 30 inches.

The water moccasin (cottonmouth) is a heavy-bodied, chunky-headed creature that may reach a length of 5 feet. It is found in



Head of a pit viper. These poisonous snakes can easily be distinguished by the presence of the pit and fangs.

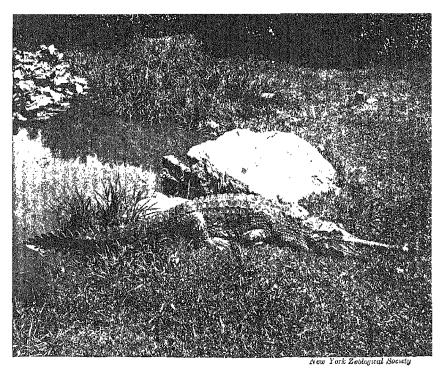
swamps from southeastern Virginia to Florida, and from southern Illinois and Indiana southward. It often rests in bushes, watching for frogs or fish.

Fifteen species of rattlesnakes are found in the various parts of the country. They are most abundant in the desert areas of the Southwest. The largest species is the diamondback rattlesnake, which may have a length of 8 feet. It is found in the swamps and hummock lands of the Southeastern states.

Other poisonous snakes. There is a family of poisonous sea snakes that have the body flattened from side to side and are true sea serpents. They are found

in the Indian Ocean and the western Pacific, and one abundant species lives along the coast of tropical America. They grow from 3 to 8 feet long. They swim well but crawl very slowly on the land. The coral snake of our Southern states is related to them, as are the cobras of the Old World.

The bushmaster and fer-de-lance of Central and South America are allied to our pit vipers (copperhead, water moccasin, rattle-snake) rather than to the venomous serpents of the Old World. The most dangerous of the snakes is the hooded cobra (cobra de capello) of southern Asia. When disturbed it raises the front part of its body, spreads its neck, hisses, and strikes at the first opportunity. The king cobra (not one of the hooded cobras), which is 10 or 12 feet long, will even rush forward to attack. In India many persons each year die from cobra bites.



A gavial of India. It seems like a creature of Mesozoic time.

THE CROCODILES AND THEIR RELATIVES

Only twenty-one living species are in the crocodile group. Besides the crocodiles proper the group includes the alligators of the southeastern United States and China, the gavials (gā'vĭ-als) of India and the East Indies, and the caimans (kā'mans) of tropical America. They are lizard-like in form, but the jaws are extended into a long snout. The nostrils are on the end of the snout and the eyes are raised so that the animals can float in the water with only the eyes and nostrils exposed to the air. The skin is thick and leathery, with bony plates buried in it. The nostrils and ears can be closed to shut out water and there is a valve in the back of the throat that closes the trachea so that food can be seized under water without flooding the lungs. The tail is flattened from side to side like that of a fish and in many other ways the crocodiles are adapted to an aquatic life.

A few species of crocodiles are man eaters, among these being the African crocodile, the "mugger" of the rivers of India, and a salt-water form which is found in India and about the Philippines and other islands south of Asia. A species not dangerous to man occurs in the southern part of Florida and in Central and South America. It grows to a length of 14 feet and in Florida digs burrows in the banks, in which it hides. The largest crocodiles are as much as 30 feet long and they sometimes knock animals into the water or within their reach by a tremendous blow with the tail. They are the heaviest of all living reptiles and they are as powerful in the rivers as the giant serpents are on land.

The American alligator grows to a length of 16 feet, but most of them are killed before they mature. It is less active and less fierce than the crocodiles and is not dangerous to man. It builds a nest of vegetable matter and earth and deposits in it from twenty to forty eggs which hatch from the heat of the sun and of the decaying vegetation. Its food consists chiefly of fishes and turtles, but the larger ones can pull animals like pigs and dogs under water and devour them. During the breeding season the males advertise their presence by a deep bellow.

THE TURTLES AND TORTOISES

If no one in the world had ever seen turtles and then they were suddenly discovered there would be great excitement over such peculiar animals. They differ from all other reptiles in having horny shearing beaks instead of teeth and in having the body more or less completely encased in armor. All of them have wide, heavy bodies, while the bodies of other reptiles are long and slim. The upper part of the shell is made by a widening and joining together of the ribs and the lower part from the sternum (breastbone). The hip and shoulder bones are inside the ribs, which is indeed a strange arrangement.

In general the distinction between a turtle and a tortoise (tor'tŭs) is that a turtle has paddles or webbed feet and lives in water, and a tortoise lives on the land. Several genera of hardshelled fresh-water forms that include species sold on the market for food are called "terrapins."

Some of the turtles and tortoises are carnivorous, some are



Sphenodon of New Zealand. It is a dinosaur, the last living representative of a great line.

plant eaters, and some eat both vegetable and animal food. The eggs are more rounded than those of snakes; they are covered with a tough membrane and are hidden in the earth or sand. During the winter our Northern tortoises burrow in the earth and the turtles hide themselves in the mud.

There is found in New Zealand a reptilian creature, Sphenodon (sfē'no-dŏn), some 2 feet in length, that is evidently a lone survivor of an old-time reptile line. It has an organ like a third eye in the middle of its forehead; its tail is flattened from side to side; its lower surface is covered with square plates; a crest of spine-like scales runs along the middle of the back. It is regarded as the last of the dinosaurs — a small surviving relative of Stego-saurus, which carried a row of upright bony plates on its back.

THE TRANSITION TO A LAND LIFE

The first vertebrates undoubtedly were water animals. Fossil fishes are found in Paleozoic rocks that were deposited long before there was vertebrate life on the land. The development of the amphibians through an aquatic stage and the presence of gill slits in the embryos of mammals and birds point back to a water ancestry. Through forms perhaps similar to the lungfishes a simple air-breathing apparatus was developed and land life for the vertebrates began. Many of the bottom-living fishes use their fins in walking about, and a few fishes can even climb bushes and trees. The limbs of the land vertebrates are direct developed ments of the pairs of pectoral and pelvic fins.

The passage from the water to the land was made by the amphibians, but they are only partially adapted to an existence in the air. They have moist skins that do not protect them from drying. Their eggs are soft and jelly-like and can develop only in water, and the young have gills instead of lungs. They are, therefore, limited to moist habitats and to locations where there is water for the rearing of the young.

It was the reptile group that completed the transition to a land life. They developed a dry, scaly skin that enabled them to withstand drying. They added a considerable food supply to the eggs and covered them with a tough, membranous skin that permits the young to develop in the egg without water and to reach a considerable size before hatching. The presence of snakes and lizards even in hot desert regions and the fossil remains of the dinosaurs are proof of the ability of the reptiles to lead a true land life.

There is, however, one lack in the adaptation of the reptiles for life on the land. Have you noticed that the larger reptiles are confined to the warmer parts of the earth? Where there are cold seasons only the smaller ones that can hide away when they are dormant can survive. For full success under the changing conditions of the land, large animals must have a heat-regulating mechanism.

UNIT COMPREHENSION TEST

- A. To what phylum do the vertebrates belong? What are the characteristics of this phylum? From what do the vertebrates receive their name? What is the general vertebrate plan? Describe the early development of the vertebrate body. Which important organs develop from each body layer? Define: alimentary canal; mucous membrane; epithelium; epidermis. What body parts make up the locomotor system? What is meant by the axial skeleton? the appendicular skeleton? Describe the circulatory system of the fish, naming the vessels through which the blood passes. What is the function of glands? What is the structure of a simple gland? Define: secretion: endocrine: hormone. What are the three parts of the primitive vertebrate brain? Define: cerebral hemisphere; cerebrum; optic lobe; optic thalamus; hypothalamus; cerebellum; medulla oblongata; cerebral cortex. Where is the instinctive and emotional center supposed to be? the seat of consciousness and thought?
- B. Describe the body and external organs of a fish. What are the principal internal organs? How is reproduction carried on among fishes? What explanation is offered for the migrations that some fishes make at the breeding season? How did the air-breathing organs of lungfishes originate? What evidence is there that the fish group is of unusual vigor and variability?
- C. What are the two principal divisions of the amphibians? What kind of animals are the salamanders? Mention some of the members of the salamander group and describe them. What are the characteristics of the frogs and toads? On what do they feed?
- D. What are the groups of living reptiles? What characteristics distinguish the reptiles from the salamanders? How many species of lizards are there? Where are the iguanas and monitors found? How large is the largest of the monitors? Mention some of the kinds of lizards found in the United States. What reason is there to believe that snakes once had limbs? How large are the largest snakes? How does a snake crawl? What are the characteristics of a snake's body? On what do the harmless snakes of our country feed and how are some of them beneficial to man? How many kinds of poisonous snakes are there in the United States? How can the coral snake be distinguished? What three kinds of pit vipers are in the United States? How can these snakes be distinguished from non-poisonous kinds? What are some other kinds of poisonous snakes? What are the more important members of the crocodile group? How large are the largest of these? What is there unusual in the structure of turtles? Describe Sphenodon.

SUGGESTED ACTIVITIES AND APPLICATIONS

- 1. In your notebook make a sketch of your idea of a primitive vertebrate. (Consult pages 836, 837.)
- 2. Observe a goldfish in an aquarium. Which fins are used to maintain balance and position in the water? Watch the movements of the mouth. Why are they continuous? Are they synchronized with movements of the operculum? Identify all the fins. In many fishes the body is greatly shortened so that the pelvic fins may be almost below the pectoral ones.
- 3. Open a fish (goldfish, carp, perch) and examine the internal organs. Trace the alimentary canal through its entire length, identifying and naming each part. Locate and give the function of the swim bladder. Look for the heart. Cut longitudinally through the muscles of the body and look for body segmentation.
- 4. Examine the mouth and gills of the fish. Note the teeth. How is the food prevented from passing out through the gills? Remove a complete gill from a freshly killed specimen. Note the fine filaments. Examine some of them with the low power of the microscope. What is the function of gill filaments?
- 5. Examine a preserved frog. It is one of the best of the vertebrates on which to make a detailed study of organs and body structure. If time permits, make an anatomical study of the frog according to directions in the workbook accompanying this text. (The development of the frog and a study of the live frog are taken up under Unit 21.)
- 6. Make a terrarium by placing in an empty aquarium or other glass vessel mosses, small ferns, or small evergreen herbs. Provide a shallow vessel of water. Cover the terrarium with a piece of glass.

In the terrarium place salamanders, small frogs, or a small turtle. In a second terrarium lizards or small snakes may be kept. Small turtles of water-living species make interesting pets.

7. Examine the preserved head or the skull of a pit viper. If the entire head is available, note its triangular shape and the narrow neck. Look for the pit and the fangs. The presence of these distinguishes the pit vipers from non-poisonous snakes.

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Cornelia Clarke

UNIT]() THE WARM-BLOODED VERTEBRATES

Life advances to still higher levels. Warm blood allows continuous activity throughout the year.

"Warm blood provides the temperatures at which nerves and muscles work best. It leads to a higher order of development." SARAH ANDREWS

BIRDS AND MAMMALS

QUESTION FOR CLASS DISCUSSION

What is meant by a generalized and a specialized species? Give examples of each among birds and mammals.

ON THE land in the colder parts of the earth cold-blooded animals are only part-time animals. Each year when the cold blankets the earth, the snails go into winter quarters. The insects die or hide away. The toads and lizards and snakes and tortoises take refuge in sleep. For all practical purposes these animals live during the warm season and drop out of existence when cold comes. A region of cold winters that had only cold-blooded animals might as well for a part of the year have no animals at all.

In this unit we shall study the warm-blooded vertebrates, animals that have found a way to keep up the temperature of the body and remain active even when the air is cold. There are two groups of these, the birds and the mammals, and they are not closely related. Each group developed independently from cold-blooded reptiles and each worked out the warm-blooded plan for itself. Briefly, a bird may be defined as a warm-blooded vertebrate that possesses feathers and a beak, and a mammal as one that has hair and feeds its young on milk. The development of body coverings that retain the heat is in keeping with the plan of having warm blood and remaining active during the winter months.

The birds are not large animals, as are some of the fishes, reptiles, and mammals, and the largest of them are ground birds like the ostrich, or swimmers like the penguins. A robin or a swallow is light in weight, and the great southern albatross with a wing spread of 11 feet does not compare in weight with a fish or mammal

that looks less than half its size. In our thinking we exaggerate the size of birds because of the bulkiness of their feathers and the spread of their wings. Heaviness of body is not compatible with flight.

The mammals are much nearer than the birds to the general body form of the old dinosaurs, but they have not adopted the warm-blooded plan so completely. Many, even of the placental mammals, go into a dormant condition when winter comes. They cannot migrate so readily as the birds and they hide away in burrows or nests when the cold comes. Some of the placental mammals are the largest of all animals.

The great physiological advance made by these groups is in the ability of the birds and most mammals to maintain an even body temperature at a high level. This insures not only constant activity, but also a temperature of the tissues at which the muscles and nerves can work efficiently. The plan, however, brings with it problems. The maintenance of the individual requires a heat-regulating mechanism and a large and constant food supply. A reproductive scheme that will provide the young with warmth as well as with food is necessary. In the warm-blooded vertebrates life reaches its highest levels, and to meet the new difficulties encountered new adaptations are required.

Problems in Unit 10

- 1 What are the characteristics of the birds?
- 2 What are the special features and adaptations of the body of a bird?
- 3 What are the distinguishing characteristics of the monotremes?
- 4 What are some of the more important marsupial types?
- 5 What are the principal groups of the placental mammals?



Arkansas kingbird



Barn swallow



Shrike



Chipping sparrow

Four of the small land birds. The kingbird and the swallow are expert fliers that catch insects on the wing. The shrike kills mice and small birds and lives as a bird of prey. The chipping sparrow is a seed eater, as its short, stout beak indicates. (Illustrations from Fish and Wildlife Service.)

PROBLEM ONE

What Are the Characteristics of the Birds?

Birds are the supreme fliers and the most striking thing about them is their adaptation for rapid travel through the air. Physically the bird is a specialist in flight. The bones are hollow and The feathers and wings are fitted for lifting the light in weight. body and driving it forward. The tail serves as a rudder in flying, as a brake in stopping, and as a balancer when the bird lights. The bones of the trunk are fastened solidly together and give a firm attachment for the powerful muscles that work the The body is streamlined, the wide breast of a swallow or a pigeon throwing the air aside and allowing the tapered body to follow through the opening with a minimum of "skin friction" or backward drag of the air along the sides. One might think that a body with a sharp front part that would cut the air like a knife would go through with the least resistance, but experiments show that a bird-shaped model with a wide front is the correct one. Airplane bodies and whales have this same general shape.

Intelligence and instincts of birds. In their nervous and mental equipment also the birds are specialized. Animals have instincts — connections in their nervous systems that cause them to do certain things without being taught or without going through a learning process. In addition, the higher animals have memory and intelligence through which they learn to perform other acts. The instincts and intelligence are independent developments. An animal (ant, bee, spider) may have very complicated instincts and little intelligence, or it may have intelligence without so elaborate an equipment of instincts.

In the instincts, which guide them in the building of their nests, the rearing of their young, and their migrations, the birds are wonderful. Of intellect they have received no great share. They can be educated to a degree, as those who have fed hens or ducks or turkeys know, but in intelligence birds are not to be compared with many animals of the mammalian class. Their strong points



Fish and Wildlife Service



are their warm blood, quickness of movement, ability to fly, and a highly specialized set of instincts that are adequate to guide them in their daily life. With this equipment the birds did very well until the advent of modern man, without bothering too much about their cerebrums.

Eggs and their care. The eggs of the birds are large, with a food supply in them that allows the young to reach a consider-

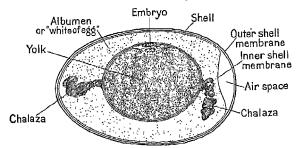
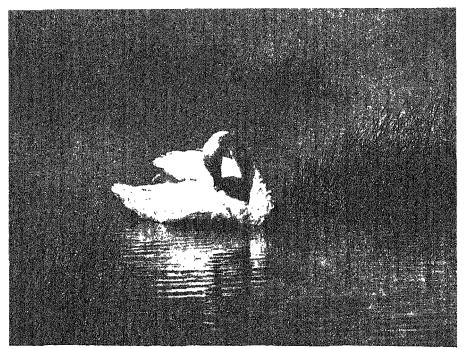


Diagram of a bird's egg. The chalaza shown is a strand of ropy albuminous materials that holds the yolk in place.

able size before they hatch. The yolk is the egg proper. It consists of a large supply of food (protein, fat, minerals, vitamins) with a single living cell on one side. This is fertilized by a sperm and then, as the egg passes down the oviduct, a gland in the oviduct wall secretes a large additional protein supply about the yolk in the form of clear albumen, or egg white. Another gland then places a thin membranous covering about the egg and finally the shell gland encloses it all in a solid calcareous (carbonate of lime) shell. The plan of developing the young in large eggs outside the body of the mother lightens the mother bird for flight. The firm shell makes the eggs able to support the weight of the parent bird in the nest.

The photographs on the opposite page show examples of the instinctive wisdom of birds. The wood pewee conceals its nest by planting moss over it. It brings water in its beak to keep the moss growing and bright green. The flicker excavates for a nesting place a hollow in a tree or post. Its eggs and young are protected from the weather and are safe from ground animals. The ground-nesting ovenbird makes the entrance to its nest at the side. The nest from above looks like a small heap of dry leaves and grass.



Fish and Wildlife Service

The trumpeter swan. Only a few individuals of the species remain. It is one of the birds that the government conservation service is trying to protect against its human foes.

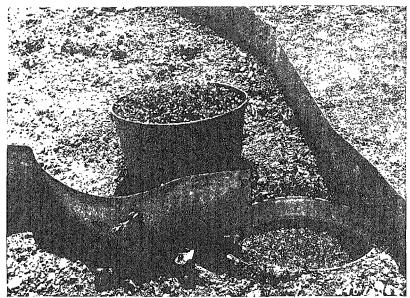
Because birds are warm-blooded, heat is necessary to cause the development of the embryo within the egg. This is supplied by the mother bird, or in some species by both the parent birds. Most species build nests in which the eggs are laid and incubated and the young are reared. The young are fed and carefully attended by the parents, and a large percentage of the eggs produce adult birds. In caring for the eggs and the young the birds display an instinct that has its roots far back in the animal line. The thousand-legged worms stay with the eggs until they hatch; some of the fishes guard the eggs and the young; the mother python lies coiled on her eggs. In building nests and incubating their eggs the birds have only carried out more perfectly what lower forms have done in a simpler way.

Troubles of birds. Birds have exceedingly keen eyes and good ears; they are alert; they have the very great advantage of flight; and among the other wild creatures of the earth they do

well. It is in man and his activities that they have met their first great check. They have suffered exceedingly from the draining and clearing of their breeding places, and even wings are not quick enough for escape from guns. Further, the men who use the guns are now carried by automobiles to the most out-ofthe-way places and by boats to the ends of the earth. are quite unable to cope with this new foe and in recent times they have passed into the position of so defenseless a group that a number of their species have been exterminated and many others are becoming rare. The migratory game birds need protection especially from those who lie in wait for them as they journey between their summer and winter homes. The smaller birds. too, need safe nesting places and the winter residents require food in times of snow. Many regions have lost half their birds in the past fifty years and the movement to protect them has come The greatest need of many of the smaller birds none too soon. is thickets and coverts where they can be safe from their foes.

Biological relationship of birds. In nature each species holds the place it occupies in the presence of its natural enemies, and if the enemies of a species are removed it is likely to multiply and become much more numerous. The smaller birds are the natural enemies of insects and it is man's misfortune that by his hunting and by his interference with the feeding and breeding of birds he has destroyed the former balance of nature and substituted a new balance that contains fewer birds and more insect life.

In Salt Lake City there stands a shaft bearing on its top a gull. It is a monument erected by a grateful people to the gulls because of services rendered by these birds to the early settlers of the state. One summer a plague of mole crickets appeared that threatened to destroy all the crops. The pioneers had no way to combat them and such were the numbers of the invaders that all hope of having a supply of food for the coming winter seemed gone. Then the gulls came — came by hundreds and thousands, with voracious bird appetites — and when they had finished the crickets were no more. The winged friends of man had come to



U. S. Department of Agriculture

Mole crickets in Wyoming. A metal fence is set in the pathway of the insects and they are directed toward sunken tubs that contain low-cost oil. A monument to the gulls in Salt Lake City commemorates the saving of the pioneer settlers from an invasion of this kind.

his rescue when he was hard pressed by his insect foe and very fittingly the monument with the gull atop stands in commemoration of the event.

What happened in the early days of Utah is happening all the time in a less dramatic and less intensive way. Many of our smaller birds live almost entirely on insects and practically all of them feed their young on insects. The birds appear each spring as a great natural check on the crop of insects that each succeeding summer brings, and because of their relation to insects the importance of the birds to us can hardly be exaggerated.

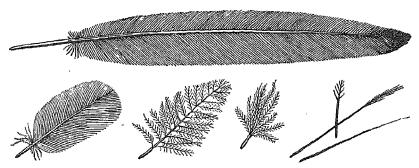
PROBLEM TWO

What Are the Special Features and Adaptations of the Body of a Bird?

As soon as one sits down to look at a bird he realizes that he is studying a unique and highly specialized animal. One may mistake a salamander for a lizard or think that a barnacle is a mollusk, but a single glance reveals whether or not an animal is a bird. Let us begin this study with the feathers, which are structures peculiar to the birds.

Kinds of feathers. Feathers may be divided into three main types. First are the *contour feathers*, which outline the shape of the bird. These have a central shaft, the lower part of which is hollow and is called the *quill*. Attached along the sides of the shaft are *barbs*, which are hooked together by little branches called *barbules*.

On the wings and tail some of the feathers are long, with a strong central shaft and stiff barbs, forming a pliable but yet resistant organ adapted for flight. These long, strong feathers are often called the *quill feathers*. The contour feathers on the body are smaller and softer and overlap each other, serving in a most admirable way to retain the body heat in flights through



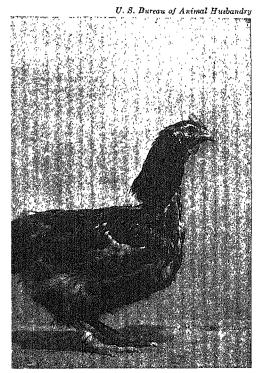
Types of feathers. Above and at the left are contour feathers. Below in the center are down feathers, and to the right filoplumes, or hair feathers.

cold air. In water birds these feathers lie so close that when oiled they form a waterproof coat. On the back at the base of the tail is an oil gland. With its beak a bird presses the oil from the gland and rubs it over its coat.

The feathers of the second type are the *down feathers*. They have a soft, short shaft and the fine barbs are not fastened together by hooked barbules but branch out in a loose, fluffy way. These feathers in the adult bird lie between the contour feathers and form a downy undercoat well suited to retaining the heat. In some down feathers the barbs arise in a cluster directly from the top of the quill. The covering of newly hatched chicks and ducks is made up of feathers of this kind.

The feathers of the third type are the *filoplumes* (fil'o-plooms), which on a picked fowl we usually call hairs. They have a slender hair-like shaft with only a few tiny barbs at the apex.

Moulting. Snakes shed their skins and birds shed their feathers or moult — the old feathers drop out and new ones grow

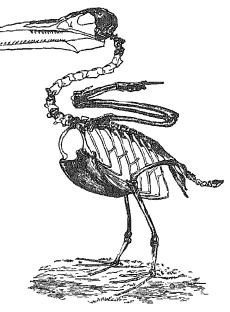


in their places. Some birds shed the outer covering of the claws and a few shed also the covering of the beak. Usually the moult takes place in the late summer, but in some species there is a partial moult in the spring also. In most species the large feathers of the wings are shed so gradually that flying is not interfered with, but ducks and rails shed these feathers so completely at one time that they are flightless until

A moulting hen. A bird grows a complete new coat of feathers each year.

the new feathers grow. In the penguin the new feathers grow and carry the old ones outward ahead of them on their tips. When at the last the bird strips off the old coat in large patches a full-grown new coat is already present beneath.

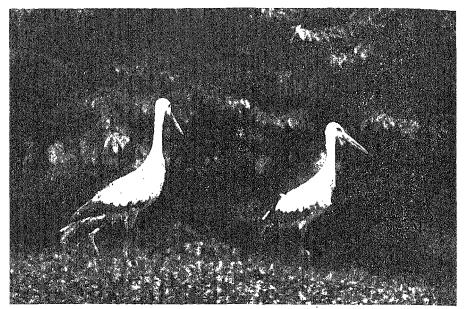
In some cases, at least, moulting is a tremendous strain on the health of a bird. Hens during a moult cease laying; the head is pale and often the hens are miserable. A naturalist who spent some time among the penguins reports that during the moulting season these



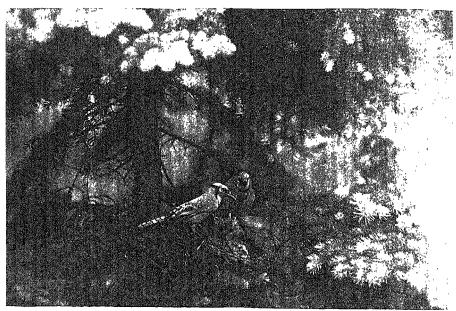
Skeleton of Ichthyornis, a fossil flying bird. The sternum is keeled. The body has the form of a modern flying bird. (After Marsh.)

birds suffer greatly and if, as occasionally happens, the moult begins during the breeding season the parents are unable to care for the young. Mammals shed their hair in the spring, but the growing of a new coat does not seem to affect them as the growing of new feathers affects a bird.

Body of the bird. If now we turn to the body of the bird we see that certain sacrifices have been made in exchange for the ability to fly. The skeleton of the trunk is fixed and the body, like that of a turtle, is a solid block that cannot be bent. Only the head and limbs are movable. Since the forelimbs are devoted exclusively to flying, there are only two legs left for walking and there are no forepaws or hands to carry the food to the mouth. The beak must serve as hands and if the bird wishes to arrange even a feather it must move its head about. Most of the movements of a standing or perching bird are movements of



European storks, typical representatives of the wading bird group.



They are small members of the crow family and are perfectly adapted for a forest life.

416 Northern blue jays.



Black-footed penguins. The penguins are highly specialized water birds. They use their wings as paddles and swim under water with great speed. It is probable that their ancestors and those of the great running birds never did fly.





On the left is a Chilean sea eagle, a typical representative of the falcon line. The hawks and eagles are swift, untiring fliers, and their beaks and talons fit them for a predatory life.

On the right is the South American great-billed rhea, one of the giant runners. It has no keel on the sternum and the wings are small. (All photographs on this and the opposite page from the New York Zoölogical Society.)

the head and in keeping with this fact we find that the neck is long and highly flexible and the head small.

The shoulder of the bird is braced not only by the wishbone (the two collarbones united), but also by a larger bone, the coracoid, on each side of the body, which extends from the sternum to the point of the shoulder blade. This arrangement is quite different from the one we find in our own skeleton, but it gives a firm base from which to operate the wings. One fifth of the entire weight of a flying bird's body is in the muscles of the breast alone, and when we know this fact we understand the need of firm shoulders for the attachment of the wings. In the flying birds the sternum has a keel, which gives room for the attachment of the great flying muscles. The running birds lack this keel.

The limbs. The limbs too are highly specialized. The wing has in its upper part a single bone, the *humerus*, and in the middle portion two bones, the *radius* and *ulna*, exactly as our



Bone of a bird. It is hollow, which gives lightness. Within is a network of delicate bracing that provides the necessary strength.

arm has. But here the resemblance to the arm ends; for what corresponds to our wrist and hand is bent outward and backward, the bones in it are much united, and of the "fingers" only two and the thumb remain (page 472).

In the hind limb the drumstick corresponds to the part

of our leg below the knee, and in it one of the bones is reduced to a mere splint. Then the bones of the ankle and foot down to the toes are united to make a shank and the walking is done on the toes. Usually there are four of these, but the ostrich has only two and the rhea has three. In the family of ground birds to which the hen, quail, and pheasant belong the back toe is elevated and small.

Alimentary tract. In its internal organs the bird is in general similar to other vertebrates, but there are modifications that are peculiar to the birds alone. The toothless beak is not

adapted for chewing; so the food must be made ready for digestion in another way. This is done by softening it in a great enlargement of the esophagus which is called the *crop*, and by grinding it in the *gizzard*, which is the back part of the stomach and has greatly thickened walls. The seed-eating birds habitually eat small stones, which are retained in the gizzard. When the strong muscular walls of this organ press in and work the food about, the stones make a very satisfactory substitute for teeth.

Kidneys. The two rather shapeless kidneys in a bird lie against the bones of the back. They excrete protein wastes as solid white uric acid which passes out of the body with the alimentary wastes. In most of the vertebrates the protein wastes are taken out of the body in solution in water. The birds by excreting these wastes as solids dispense with the water and thus lessen their weight in the air. The ducts from the kidneys, the oviduct, and the intestine all empty into a common cavity, the cloaca (klo-ā'ka), at the back of the body.

Respiratory and circulatory systems. In their respiratory system the birds have several distinctive features. First of all, the lungs lie flat against the back instead of being free in the chest cavity. Second, there are long thin-walled air sacs—really extensions of the lungs—that run along the back and sides within the body cavity and may even extend into the bones. These have not many blood vessels in their walls and are probably not of much use in giving oxygen to the blood and taking carbon dioxide from it. They communicate with the lungs, however, and are believed to help the bird in respiration as it flies.

It is supposed that as the wings are moved the air sacs within the body are alternately compressed and allowed to expand, and that this alternate compression and expansion of the air sacs drives the air out of the lungs and draws it back in as would be done by a series of very rapid short breaths. It is difficult for us to breathe when we are exercising violently, and it has been suggested that when flying a bird does not breathe in the ordinary way at all but that its lungs are ventilated by the pump-

ing movements caused by the contraction of the powerful muscles that move the wings.

The heart of the bird is proportionally unusually large. It has a double circulation through it in which there is no mixing of the impure blood with the pure.

The bird as a flying machine. Not only in the form and structure of its body but also in its physiological processes is the bird fitted for the high energy level of life that it leads in the air. The alimentary system of a bird is capable of digesting large quantities of food; its lungs can take in a copious oxygen supply to unite with the food; its circulatory system is a most efficient distributing system; and the life fires burn hot within its cells. The bird is a high-powered flying machine, so perfect that mechanically the best airplane is not worthy of comparison with it. With perfect nonchalance and with no instruments the little golden plover takes off for a 2500-mile non-stop ocean flight from Labrador to northern Brazil. The food stored in its body furnishes sufficient fuel to carry it to its destination. Something not possessed and not understood by us guides it on its way.

Diversity and adaptations among birds. There are many orders of birds and they form a more diverse group than some of us realize. The great runners, like the ostrich, rhea, and cassowary, are a distinct line. The penguins are far removed from all other birds; and the sea birds, shore birds, birds of prey, waders, and swimmers include a great assemblage of forms very different from the songbirds that nest about our homes. All of these have the rigid type of bird body, but there is endless variation in the necks, beaks, and limbs.

The seed-eating birds have short, stout beaks. The flesh eaters have hooked, tearing beaks. The feet of the quail are fitted for running; those of the robin are fitted for perching; those of the hawk are armed with talons for seizing its prey. The legs of the waders are long, and their necks and beaks are correspondingly long for reaching down into the water and mud from which they obtain their food. Visit an aviary or a museum or study the birds about you from day to day, and you will see that

the body and members of each kind are adapted to its habitat and its way of life. Watch a flicker as it perches, climbs, runs, and adjusts itself to any angle on the side of a tree, and you will see a beautiful example of bird adaptation to a special mode of life. One of the best places in all the biological world to study adaptations is among the birds.

The great adaptation of the birds is for travel through the air. Wings have made their life vastly different from that of animals that lack them. Many birds hardly come down at all from the trees. The cliff swallow sticks its mud nest under a sheltering cliff or the eaves of a barn and feeds itself and its young from insects that it catches in the air. Sea birds use as their resting and nesting places lonely rocky islands and inaccessible shelves on cliffs where the reptiles and mammals The birds are able to choose for their homes cannot come. and nesting sites places that are inaccessible to other animals of any size and that are therefore safe for themselves and their In physiology one of the ways of determining what an organ does is to observe an animal which has lost that organ, noting the effect. If you can imagine the predicament of a bird deprived of the power of flight you will understand how the whole way of life of common birds, the structure of their bodies, and even the processes that go on within their cells are built about wings.



The duckbill, or platypus. It is a representative of the egg-laying group of mammals, which is now almost extinct. The painting was made by the noted artist-naturalist, E. Bruce Horsfall, through whose courtesy it is here reproduced.

PROBLEM THREE

What Are the Distinguishing Characteristics of the Monotremes?

We come now to the last class of the vertebrates, the one to which we ourselves belong. This is Class Mammalia, the members of which are characterized by having hair and feeding the young on milk. There are three subclasses of the mammals: the *monotremes*, or egg layers; the *marsupials*, which carry their young in pouches; and the *placental*, or modern mammals.

The monotremes and the marsupials are old groups and over much of the earth they are extinct. The egg layers are now represented by only three living species, all found in Australia and the neighboring islands. They have several characters that mark them as connecting links between the modern mammals and the old dinosaurs.

The duckbill. One of the monotreme survivals is the platypus, or duckbill, of Australian and Tasmanian streams. It is a flat little animal with an extreme length of about 2 feet. It is fitted for aquatic life, having webbed feet and waterproof fur. It swims expertly by pulling itself through the water with its forelimbs, and although its legs are very short it can run with surprising rapidity. It is shy and wary and is now rare, having been almost exterminated for its fur. The jaws of the platypus are toothless and form a broad beak like that of a duck. The tail is broad at the base like that of a crocodile or a snake, not a slender organ like the tail of a dog or a pig. Unlike all the higher mammals the duckbill has a poison gland in the thigh which is connected with a bony spur on the heel of the hind foot. This venom apparatus is used very effectively in defense.

The food of the platypus consists of tadpoles, shrimps, worms, and other small animals. Some of these it captures from the water. Some it secures by probing in the mud. It has cheek pouches which it fills from the bottom of the stream. Then it comes to the surface to sort over what it has found. A supply of

nourishment is stored in the fat tail and at times the platypus dens up in a state of dormancy and sleeps. It is very playful and gentle in captivity. One that was kept in a pool for four years delighted in chasing a mop through the water and was fond of boiled egg.

The male and female duckbills live separately. Each makes for itself a long burrow with one entrance above water and one below water in the bank of the stream in which it lives, and in this it sleeps during the day. In a chamber of her burrow the female makes a nest of grass, roots, and leaves and here she lays two eggs (very rarely one or three) a little more than half an inch long. Then the mother duckbill incubates the eggs by sleeping on them until they hatch (page 256).

The eggs of the duckbill are small and the young are very immature when they hatch. They have, however, the instinct to snuggle up against the mother's body and there they find a kind of food that is new in the animal world. In a patch of the mother's skin the sebaceous glands (which over most of the body produce oil for the hair) are modified so that they secrete milk. This flows out and the young lick or suck it from the hairs. On this food they grow and thrive. Soon they are ready to go out and try to catch shrimps or root in the mud for worms. In two months they leave their mother and start an independent life.

Because it has hair and because it feeds its young on milk, the duckbill is a true mammal. Yet it has not done much more than get inside the door of the mammalian house.

The spiny anteater. The other kind of egg-laying mammal is the spiny anteater, or *Echidna* (e-kĭd'na), of which there are two species (page 461). It lives in burrows and has strong claws with which it tears down anthills. It has a long beak, no teeth, and a long sticky tongue with which it licks up the larvae and pupae of ants. Its body is covered with hair mixed with spines and, as in the duckbill, the male has a poison spur on the hind foot. It escapes from its enemies by rolling itself into a ball or quickly sinking itself in the sand and presenting its spiny back. It is not a very intelligent animal, but it is less stupid than its

appearance might indicate. In the wild state, ants are its only food.

The echidna lays a single egg about the size of a sparrow egg. This is carried in a pouch-like fold of the skin on the abdomen until it hatches. The young one is nourished in the same way as the young of the duckbill. It remains in the rudimentary pouch on its mother's abdomen until it is 3 or 4 inches long. The echidna can be tamed and it learns to like bread and milk, which it licks up with its long tongue. Like the duckbill, the echidna may go into a period of dormancy in which it lapses back into old reptilian sluggishness. At these times the heartbeat is feeble, the oxidation within the cells is slow, and the temperature may fall as much as 18° below that maintained when the animal is active.

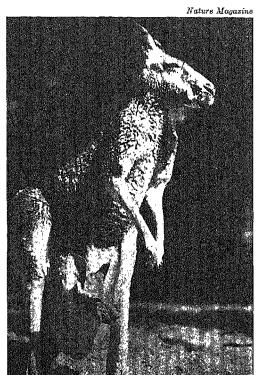
The duckbill and the spiny anteater survive only because of their ability to burrow and to defend themselves. They are not supposed to be the ancestors of the other mammals. Rather, they are highly specialized side-line species. The ancestors of the higher mammals doubtless laid eggs as these old forms do, but they must have been much more generalized animals — better fitted to eat any food that came to hand and to live out on the open land.

PROBLEM FOUR

What Are Some of the More Important Marsupial Types?

When white men first reached Australia and the neighboring islands they found no cattle, horses, deer, bears, lions, panthers, monkeys, rabbits, or squirrels. Instead they found (in addition to the monotremes) kangaroos, wombats, bandicoots, phalangers, marsupial cats, pouched mice, the marsupial wolf, and a savage carnivorous form about as big as a wildcat that is called the Tasmanian devil. All these animals are marsupials whose young are born in a very immature condition and reared by the mother in a pouch. The Australian region had a set of animals different from the animals of the rest of the world.

The marsupials illustrate in a very striking manner how by radiative adaptation an animal group becomes diversified. For a long



time they had their part of the world to themselves and the different members of the group became fitted for different ways of life. There are vegetable eaters and flesh eaters among them. There are dwellers, burrowers, and kinds that run on the ground. It is interesting to compare these marsupial forms with the forms that have arisen in the placental line.

Mother kangaroo and young. The kangaroos and wallabies are an extremely diversified group. Some of the smaller ones live largely in trees.

The kangaroos and wallabies. The most important of the marsupial herbivora are the kangaroos and wallabies, of which there are about sixty species, varying greatly in size. An old male of the largest kinds of kangaroo may weigh 200 pounds and stand 5 feet high. The smaller members of the group are timid little night feeders that live among the rocks and are no larger than rabbits or even large rats. They feed on grass, herbs, and roots and before the introduction of sheep and cattle they were the grazers of the Australian region. In some places they are still abundant enough to be a nuisance through eating the grass needed for domestic animals, but they are hunted both for sport and for food and are no longer as numerous as they once were.

The kangaroos stand on their strong hind legs and use the heavy tail as the third leg of a tripod to prop them from behind. They cover ground very rapidly by a series of long, low leaps with no pauses between them. In doing this they lean far forward and carry the long, heavy tail as a balancer in the air behind. The front limbs are short and are used chiefly for grasping. The kangaroos are peaceable and harmless, but they have a long, punishing nail on one toe of each hind foot and in defending themselves they stand up facing the foe and kick with great power.

When a band of kangaroos is pursued by dogs an old male will try to draw the dogs off after himself and away from the mothers and young ones. If surrounded, he stands with his back to a tree and defends himself by kicking. When it is possible to reach water he makes for it and wades in until a dog can reach him only by swimming. Then if a dog comes within his reach he seizes it with his arms and holds it under water until it drowns. One of the early settlers of Australia who went to the rescue of his dog was himself seized and put under water and would have been drowned but for the help of his comrades. The larger kangaroos are quite powerful animals, although, like all the birds and land animals, they are helpless before guns.

The kangaroo mother has only one baby at a time and the baby is very small when it is born. It is placed in the pouch and

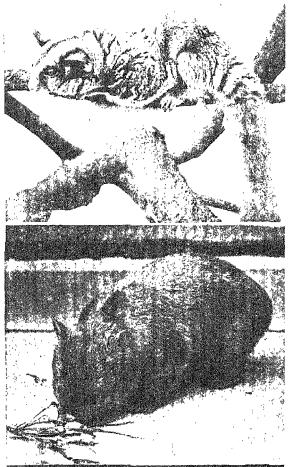


On this and the next page are shown some common marsupials.

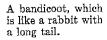
On the left is a Tasmanian devil, a savage carnivorous form about the size of a wildcat.

The Tasmanian wolf. It is remarkably similar to the wolves and dogs of the placental group.

A marsupial mouse. Like many of the marsupials it has beautiful fur. Flying phalanger, a form similar to our squirrels.



A wombat, which among the marsupials holds much the same place as our burrowing rodents.



(All photographs from the New York Zoölogical Society.)



takes hold of a nipple from which it gets its food. When it is large enough it leaves the pouch at times, returning to it to nurse and sleep and for protection at the first signal of danger. When closely pursued a mother kangaroo will take the baby from her pouch and toss it aside. Whether she does this so that she may run faster and thus have a better chance of saving her own life or because there may be a better chance for the baby to escape if it is left behind is not known. When we study the behavior of animals we see what they do, but we have no way of knowing whether there is any conscious purpose behind their actions.

The phalangers. The phalangers are a varied group that have made their homes in the trees of the wooded parts of the marsupial region. The largest of the phalangers is a woolly, tailless animal weighing about 30 pounds, that is called the koala (ko-ä'la) or Australian bear. It leads its slow, sloth-like life in the lofty eucalyptus (gum) trees and feeds on their leaves, shoots, and flowers. "As it sleeps during the day, clinging to a tree trunk, it looks like a round mass of moss, a woody excrescence, or a bunch of mistletoe."

After its single child is half grown the koala carries it on its back. Although the koala makes an interesting pet it is not known outside of Australia because proper food is not available elsewhere. It has been almost exterminated for its fur.

A large group of the phalangers are opossum-like animals that feed on leaves. Some are as large as cats and some as small as mice. They nest in hollows in the trees or build nests as our squirrels do. Another group are the flying phalangers which, like our flying squirrels, have a fold of skin extended out between the front and back legs and can glide through the air from tree to tree. Some of them give beautiful and highly valued furs. They are much like our squirrels in appearance, but they feed on leaves. In their woodlands there are no oaks or nut trees to bear acorns and nuts for them.

The wombats and bandicoots. The wombats are burrowers that look like giant guinea pigs and live, like prairie dogs, in towns. The largest are 3 feet long. They are placid, easily



James Sawders

Koalas, or Teddy bears. They are the largest of the tree-living phalanger group and feed on eucalyptus buds and leaves.

tamed animals that feed at night on roots and grass. In a zoölogical garden one of them reached an age of more than 30 years.

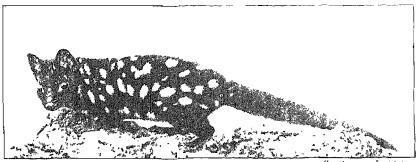
The bandicoots are quick, active, bustling little creatures that run with a half jump and half gallop. They eat vegetation and

also insects. The largest are about the size of small rabbits and the flesh is prized for eating. They are night feeders and given to entering gardens and digging out and eating potatoes and beets. Because of their attractiveness and tameness they are often kept as pets. The wombats and bandicoots correspond to our rabbits, woodchucks, prairie dogs, and ground squirrels. There is room in any fertile part of the earth for a group of rather small vegetable-eating animals to live as these animals do.

The marsupial wolf. When we turn to the marsupial carnivora we find that the largest is the marsupial, or Tasmanian, wolf. This is the size of a wolf or a large dog and is built strikingly like one. Like the dog tribe it runs by scent and although it is not very swift it has tremendous endurance and can keep up a long swinging canter hour after hour. Before the country was settled the marsupial wolf lived by running down kangaroos and wallabies and by hunting along the seashore for fish, crabs, or other food the waves might throw up. When sheep were introduced it changed its diet to lamb and mutton and became a great problem to the sheep raisers. Fossils of it are found in Australia, but it occurs now only in Tasmania, where it has been hunted until it cannot be found outside the wildest mountain parts.

The Tasmanian devil. Next in size among the carnivora is the Tasmanian devil. It is supposed to be untamable—"the most sulky, savage, villainous, unattractive, unamiable mammal that exists." It is a chunky, big-headed, short-limbed, powerful creature that kills other animals far larger than itself. It has strong front claws with which it burrows. In the days of the white man's first coming to Tasmania it was far more abundant than the marsupial wolf and was immensely destructive to the sheep and poultry of the settlers. Now its numbers have been greatly reduced and it will probably be exterminated. Like the marsupial wolf, the Tasmanian devil often prowls along the seashore searching for fish, crabs, or other food.

The marsupial cats. The marsupial or spotted cats are common over the Australasian region. Although inoffensive to look at, they resemble our weasel tribe in fierceness. The larger



Smithsonian Institution

A marsupial cat (spotted Dasyure). These cats correspond to the minks and the weasels of the placental line.

ones are about the size of our cats and the smaller species are only about half this size. They live in trees, where they make their homes in hollows in trunks. They hunt at night and their food consists chiefly of birds and small marsupials that they can overpower. They raid hen roosts as our weasels and minks do, and in the general life scheme they fill the same place as other small carnivorous forms. All of them are spotted with white. They are trim little animals whose attractive looks belie their bloodthirsty ways.

Other Australian marsupials. There are all together in the Australian region one hundred and fifty species of marsupials. They are a land and forest group of rather small animals, among which we find forms fitted for living in most of the ways that mammals can follow in their environment. In addition to the kinds we have mentioned, there is a family of carnivorous pouched mice; a marsupial anteater about the size of a squirrel; a slow-moving arboreal animal (called a cuscus) that is related to the phalangers and resembles some of the lemurs; and a mole that eats insects and goes part of the time on the surface and part of the time underground.

The marsupials are supposed to have been over the whole earth at one time and to have given way before the newer and more powerful placental mammals. They survive in Australia because there they escaped the competition of the newer animals.



James Sawders

A young opossum. Note the way it grasps the limb with its foot.

Australia has long been cut off by the sea from the other continents and with the exception of the yellow-dog dingo (supposedly brought by the black people) none of the placental mammals reached it until the coming of the white man.

The American marsupials. American marsupials are of two groups, the selvas and the opossums. The selvas are ratlike little animals, several species of which are found in South America. The opossums number about twenty-five species. They may be as small as a large mouse or larger than a cat. They are Central and South American animals, but one species occurs also over our Central and Southern states. As a group the opossums are climbers, but one species has webbed feet and is thoroughly adapted to a water life.

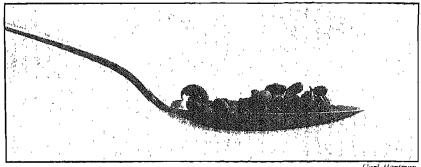
Our opossum is shaped somewhat like a rat and is about the size of a cat. It is covered with long gray hair, sleeps during the day, and hunts at night. Usually its home is in a hollow tree, and the animal spends much of its time in trees and bushes above the reach of foxes and dogs. The tail is prehensile and is freely used in climbing. On the ground the opossum is slow in its movements and when disturbed often pretends to be dead ("plays possum"). It will then submit to being shaken by

dogs, carried by the tail, or tossed about without showing signs of life.

The opossum is truly an omnivorous animal. It eats vegetation, insects, crayfish, eggs and young birds, berries, apples, corn, nuts, persimmons, or anything else that comes to hand. It will kill poultry and because it climbs well it can reach fowls when they are on a roost or in a tree. It breeds rapidly, producing two or three litters a year, with usually from six to fourteen young in a litter. The development of the eggs and young has been carefully studied; so an accurate account of the early life stages can be given.

The egg is developed in the ovary and passes down the oviduct. On its way down, a layer of white is deposited about each one and the egg is enclosed in a membranous covering. The egg is not laid, but the young starts its development within the body of the mother. The single cell absorbs the food stored within the egg, multiplies, and grows. As the outlines of the body of the young animal are laid out and the parts develop, nourishment is absorbed from the mother's blood also. In 12½ days after fertilization of the eggs the young are born. They are very immature. Eighteen of them have been placed in a teaspoon and it takes 270 of them to weigh an ounce.

It was formerly supposed that the mother opossum places the young in her pouch with her mouth, but it has been found that



Eighteen baby opossums in a teaspoon. Small as they are when they are born, they can crawl into the mother's pouch.

this is not the case. Tiny as they are, the baby opossums have front legs that are developed enough for use, and they crawl along the stomach of the mother and in some way scramble into the pouch. Any one that does not get in by itself stays out. At the very beginning the young opossums that help themselves are the ones selected to survive.

Inside the pouch each baby fastens itself to a nipple and here it lives for six or eight weeks. At two months they are covered with hair, their eyes are open, and they like to come out and climb about on their mother as she lies in the sun. Later they ride on her back as she goes on her hunting expeditions, clinging to her long hair or wrapping their tails about hers as it is curled up over her back. At three months of age they are hunting for themselves.

One of the South American opossums (the yapock) is of especial interest because of its adaptations to an aquatic life. It lives in tunnels in the banks of rivers, has webbed feet, swims and dives, and feeds on fish, crustacea, and aquatic insects. When first found it was supposed to be a relative of the otter. It is a splendid illustration of how the environment of an animal shapes it so that it is suited for the life it leads.

In general the marsupials have the same body form as the placental mammals and some of them resemble in a striking manner some of the smaller animals of the placental group. There are, however, no very large animals among them. They have produced no line of large hoofed animals and no animals corresponding to the great cats, bears, seals, whales, or the apes and man.



Fish and Wildlife Service

A prairie wolf surveys the winter scene.

PROBLEM FIVE

What Are the Principal Groups of the Placental Mammals?

Geologically the placental mammals are the newest group of animals, the ones that have come last into the world. There are more than three thousand species of them and they are flourishing today as the reptiles did in Mesozoic time. Not only are they adapted to all the varying habitats of the land, but some of them (e.g., whales, seals, sea cows) have returned to the sea for the rich supply of food that it affords. In size they range from tiny shrews and mice up to elephants and whales.

The diagram on page 456 shows the principal divisions of the placental mammals. There are sixteen orders, whose relationships are in a general way indicated by the diagram. We shall treat briefly some of the leading orders.

THE CLAW-FOOTED PLACENTAL MAMMALS

The claw-footed condition is the one we find in reptiles, birds, monotremes, and marsupials, and eight of the sixteen orders of placental mammals belong to the claw-footed group. Most of these mammals are smaller than the mammals of the other groups,

WARM-BLOODED VERTEBRATES



Fish and Wildlife Service

Shrews. Some kinds of them are smaller than mice. Although they are very abundant, they are not generally known.

although in the bears and big cats the carnivora have produced clawed animals of large size. The young of the clawfooted mammals are born in an immature condition and are usually cared for in dens or nests.

Insectivora. The insectivora are the insect eaters. Their teeth are studded with sharp points fitted for crushing up into small bits the chitinous coats of insects. The

group includes the shrews, the moles, and the hedgehogs of the Old World.

The shrews are supposed to be more nearly like the primitive placental mammal than any other animal now alive. They are plantigrade (walk on the soles of their feet). Our North American kinds are ground forms that live under stones and in shallow burrows; in the tropics there are tree shrews and water shrews that swim expertly. Shrews are abundant in our country, but they are not well known because they are usually mistaken for small mice. They roam the fields at night, feeding on insects, worms, snails, young birds, and mice. They have a bad odor and because of this escape foxes, weasels, skunks, and other animals that would prey on them. They can easily be told from mice by their long noses and sharp little spike teeth, and from moles by their front feet.

The moles are heavier than the shrews and are fitted for "swimming through the earth." Their strength is almost unbelievable. One that weighed 3 ounces not only heaved up the earth in making its tunnel but also lifted a 9-pound brick that lay on the earth. They can advance a tunnel in ordinary soil at the rate of 1 foot in 3 minutes and if dug out and placed on the surface of the ground they move as fast as a person ordinarily walks. Under a molehill is a hollow nest filled with leaves and grass in

which the naked young are born. The young grow rapidly and in 4 or 5 weeks start out tunneling for themselves.

The bats. The bats are the only mammals with real wings. They are not very different from a shrew in body but their limbs are greatly modified. There are nearly one thousand species of them (one third of all the kinds of placental mammals) and they are divided into three groups — the insect eaters, the fruit eaters, and the vampires (blood-sucking bats). Our bats belong to the insect-eating group and like the insectivora are active at night. They are wonderfully expert fliers, able to catch insects on the wing. In the daytime they hide away in hollow trees, dense bushes, or other concealed places, hanging head down by hooks on their wings. In winter some kinds hibernate and some, like the birds, migrate to warmer climates. The young are born one or two at a time and at first cling to the mother as she flies. When

they are old enough to be "hung up" the mother leaves them at home when she goes on her expeditions for food.

Some bats are blind, and in others the eyesight is poor. They seem to "feel" their way rather than to be guided by sight. A blind bat can fly through a crooked passageway without striking the wall, and while a bird will fly against a pane of glass a bat will turn aside or drop before it strikes it. To most persons bats are

The solenodon (so-lĕn'o-dŏn) of Cuba, a relative of the shrews. It has a total length of 7 inches and is regarded as a very primitive mammal. Note the plantigrade feet.





Cornelia Clarke

A hardy and familiar rodent. It depends for safety on its ability to hide and its speed in flight.

disagreeable. Have you ever noticed that the devil and evil spirits in general are pictured with bat wings?

The rodents. The rodents are a great group, both in number of species and in the abundance of individuals. They are specialized not in their bodies but in their teeth, which are fitted for gnawing. On the whole they are what we should call rather small animals. The order includes the mice, rats, muskrats, squirrels, chipmunks, rabbits, guinea pigs, beavers, prairie dogs, woodchucks, porcupines, and many other forms. Most of them live on coarse vegetable foods, but rats and mice are partly carnivorous. The young of most of them are born in large litters in an immature state and are cared for in nests. They are far more intelligent than the shrews and bats. Many of them store food for winter and a number of them (e.g., beavers, prairie dogs) live in colonies and keep a sentinel posted to warn them of the approach of a foe. In general the rodents tend to be plantigrade and many of them use the front paws to a certain extent as hands. The largest rodent is the capybara of South America, which swims as well as a water rat and weighs up to 140 pounds.

toothless The mam-Next to Australia, mals. South America is the most peculiar part of the world in its land animals. It has an order of queer animals. Edentata (ē'dĕntā'ta), that have no teeth or only a few peg-like teeth with no enamel covering. Three groups of animals are included in this order — the sloths, anteaters, and armadillos.

The sloths are tree dwellers that live chiefly in the equatorial rain belt. Through the day



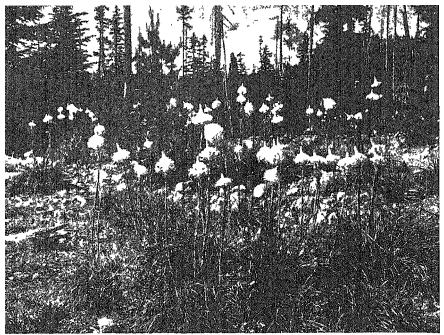
Nature Magazine

The aardvark, or "earth pig," of South Africa. It belongs to an order of its own but is related to the sloths and armadillos. It burrows, and its food is termites and ants.

they sleep, hanging back down with their long claws hooked over a branch. They draw in branches with their arms and eat the buds and leaves. They have weak muscles and move with great slowness, climbing about most carefully. They have no tail and no ears, and they do not play or show any sign of joy in life. Their air of large-eved, snub-nosed, tired sadness led the great French naturalist, Buffon, to write, "The sloth is a creature afflicted of God for some hidden reason that man cannot follow."

The Mexican coon cat, which is found in our Southwest also. It is a relative of the raccoons and of a group of other small carnivorous mammals that live in the forests of tropical America.





Nature Magazine

Beargrass in the Rocky Mountains (called also squaw grass). Many of the carnivora (raccoons, bears, pandas, and even foxes) live in part on vegetable food. The plants shown above are relatives of the lilies, and produce fleshy rootstocks which bears dig out and eat.

The edentate anteaters live on insects rather than vegetable food. The great anteater is a ground animal that is 7 feet long from the tip of its long pointed nose to the end of its bushy tail. It has strong claws for tearing up anthills. There are other smaller anteaters that live partly or entirely in trees.

The armadillos more nearly than any other mammal have developed a shell or armor. This is composed of bony plates buried in the skin. In some species the armor is in rings or bands about the body, with movable joints between the rings. Most species of armadillos feed on ants and other insects, but some kinds eat also mice, the eggs and young of ground-nesting birds, and other small animals. A South American species adds snakes to its diet, killing them by throwing itself on them and sawing back and forth with the notched edges of its armor. The armadillos live in burrows and can sink themselves into the earth with astenishing rapidity.



New York Zoological Society

The giant panda. It is a relative of the raccoons and the bears.



The raccoon. Like the bears and pandas, it has plantigrade feet.

One species of armadillo - the nine-banded armadillo - is found as far north as Texas. It is of peculiar interest because the four young which it produces at one time all develop from the same egg. In a later unit we shall return to this subject of more than one embryo from a single egg.

The carnivora. The carnivora are the flesh eaters and the order includes many families and hundreds of species. two main divisions of the order are the land and water carnivora. The land carnivora include the bears, cats, dogs, and weasels. The water forms include the seals, sea lions, sea elephants, and the walrus.

The most generalized of the carnivora are the bears, pandas, They walk on the soles of the feet, and some of and raccoons. them eat almost any food. The cats are a great group that are found in the wild state all over the earth except in the Australian region. The house cat is the smallest of them and the tiger the largest. They are highly specialized for a hunting life. The dog family is a prominent one that includes several kinds of wild dogs



Hawaiian fur seal. Seals can live at sea, and some of them spend most of their lives migrating between their summer and winter homes. This species makes the 4000-mile journey back and forth between the Hawaiian and the Aleutian Islands.

and the wolves, foxes, hyenas, and jackals. The weasel tribe is composed of a host of bloodthirsty smaller forms that are a terror to all small life. The largest of the land carnivora are the bears and next to them are the big cats. The smallest are members of the weasel group.

The water carnivora are large animals with their limbs converted to flippers. Most of them feed on fish, but the food of the walrus is mollusks (mussels) which it digs from the ocean bed. Some of these animals are very intelligent and can be taught to perform tricks. Probably only the dog, the elephant, and the more intelligent of the primates excel them in the ease with which they can learn.

THE PRIMATES

The primate order includes the lemurs, monkeys, apes, and man. A distinguishing character of the order is that its members alone of all the mammals have nails. In general, in their body structure they are rather primitive. They are plantigrade and the teeth and digestive tract are suited to a general diet. are neither very large nor very small. The smaller members of the order, the lemurs and monkeys, are tree dwellers. Some of the larger apes lead almost wholly a ground life.

PLACENTAL MAMMALS

The lemurs. The great home of the lemurs is in Madagascar, although there are related animals in Africa and the East Indies, and fossil lemurs are found in North America. The lemurs live in trees and their feet, both front and back, are hand-like and fitted for grasping the branches among which they climb. Most of them are night animals that sleep during the day, hidden among the leaves or in hollow trunks. There are many kinds of lemurs, and their relatives, the marmosets, lorises, tarsiers, and galagos (ga-lā'gōs), add to the variety of the group.



James Sawders

Bush babies looking and listening. They are tarsiers and their home is in Africa. They are small relatives of the lemurs and members of the primate order like ourselves.

Some of them are the size of a large house cat. Some are squirrel-like and smaller than rats. Some of the little ones live almost entirely on insects. Others eat birds' eggs, lizards, fruits, or anything else they can find. The tarsiers (tar'sĭ-ers) stand on their hind feet and hop like little kangaroos.

If you should look at the lemurs in a zoölogical garden or at the mounted ones in a museum they would probably seem to you more nearly related to the foxes or perhaps to the raccoons or some of the rodents than to the monkeys. They are little four-legged animals, and their faces lack the human appearance that is found in the monkeys and apes. They have, however, gone to the trees, and they hold to the branches, not with claws as the squirrels do, but by grasping with hand-like feet. With their hands and nails they have made a start on the primate way.

The monkeys. The monkeys are another group so large and so varied that the different families cannot be described here. They are separated into two great groups, the New World and the Old World monkeys. The New World monkeys have a prehensile tail — a fifth hand by which they climb and swing in the trees. The Old World monkeys do not use their tails in this way and their nostrils are set closer together than those of the American kinds.

There are big monkeys and little ones no larger than kittens. Some are trim, neat little animals and some are almost unbelievably ugly. Some are lemur-like in general appearance and some have an ape-like aspect. They eat insects, worms, lizards, eggs, fruits, grain, seeds, and other foods. All of them are climbers, but the very largest ones, the baboons, spend most of their time on the ground.

The apes. The third group of primates is the anthropoid apes (Greek anthropos, man, + wides, like; man-like). Of these there are four kinds — the gibbon, orang-utan, chimpanzee, and gorilla. They are far more intelligent and serious than the monkeys. In them we find the nearest approach to human hand and mind. All of them are Old World, the gibbon and orang living in Asia and the chimpanzee and gorilla being confined to the equatorial forests of Africa. Recently there has been discovered in Africa the remains of a slender ape that walked upright like a man. In a later unit we shall take up the apes again for a study of their ways of life (page 783).

THE HOOFED MAMMALS

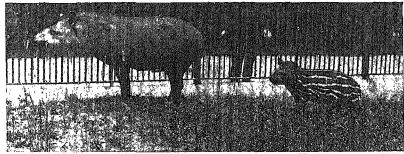
When the trees had appeared and grass had carpeted the open spaces of the earth it became possible for a vast animal population to support itself on the vegetation of the land. The rodents took advantage of this food supply and spread out as a great group of small species that escape from their enemies by hiding, climbing, or burrowing. There appeared also a vast assemblage of larger herbivorous animals, the hoofed animals, which feed on grass or browse on bushes and the lower branches of trees. These animals

have hoofs instead of claws or nails. They are placed together in the Subclass Ungulata (ŭng'gu-lā'ta), and collectively are spoken of as the ungulates (Latin *ungula*, hoof). They are the largest of the living land animals. Most of them are preyed upon by the larger carnivora, and they have keen senses that aid them in detecting the approach of enemies, and the power of rapid flight.

There is a tendency among the hoofed mammals to lose some of the five typical mammalian toes, and the two great divisions of the Subclass Ungulata are the even-toed and odd-toed orders. The even-toed ones have two or four toes and the odd-toed ones three or one. In addition there are included in the Ungulata the elephants, which have five toes and hoofs that are little more than nails, and the little conies, which look like rodents but have hoofs.

The odd-toed ungulates. The odd-toed ungulates include the tapir, rhinoceros, and horse families. It is a comparatively small group. The members of the horse family have only one toe on each foot; the others have a large center toe with a small one on each side.

Fossil and skeletal remains show that all the families of odd-toed ungulates were once well represented in North America and Europe and that they once had a wide distribution over the earth. Now in their wild state they are greatly restricted in their habitats and the tapir and the rhinoceros are comparatively rare. All of them are specialized animals, the members of the



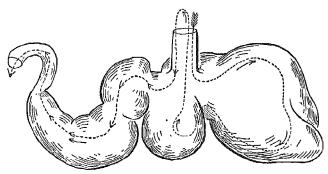
New York Zoological Society

South American tapir. It is a member of the odd-toed ungulate group, which, except for the horse tribe, is almost extinct.

horse family being adapted to life on open plains. The teeth are fitted for cropping short grass. The number of toes is reduced to one on each limb. The legs are powerful and the whole body is fitted for running. The intelligence and character of the horse are such that it is one of the animals man can most easily train for his own use.

The even-toed ungulates. The even-toed is by far the largest of the ungulate orders. It includes the pigs, the hippopotami, the ruminants, and the sea cows. The pigs are the most generalized. They eat anything and they do not flee in wild terror from the carnivora as the sheep and deer do. Next to the pigs in lack of specialization is the hippopotamus. Its four spreading toes all come to the ground and the small hoofs are like large nails on the toes. A full-grown one of the common species weighs about 4 tons.

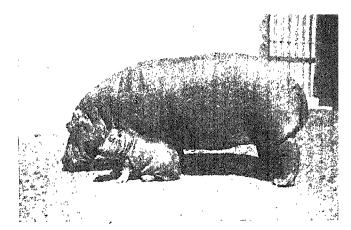
All the rest of the even-toed ungulates are ruminants, or animals that chew the cud. They are equipped with the highly specialized ruminant stomach, the characteristic feature of which is the division into compartments. The first compartment is a great paunch into which coarse unchewed food drops and from



The stomach of a ruminant. When coarse food is swallowed it first enters the large compartment (paunch) shown on the right. It is then taken up to the mouth again and chewed to a fine state. When it is swallowed the second time it enters the lower part of the stomach, as the arrows indicate. The advantage of the ruminant stomach is that the owner can gather food hastily and retire to a place of safety to masticate it.

Hippopotamus, one of the eventoed hoofed animals. Next to the elephant it is the heaviest of the living land mammals.

> National Zoblogical Garden



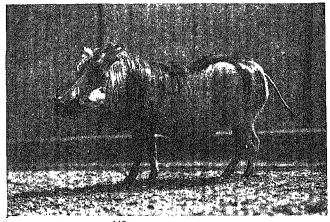


Conies. They are about the size of rabbits and their closest living relative is the elephant. They look like rodents, but they have tiny hoofs that class them among the ungulates.

Zoölogical Society of Phyladelphia

African wart hog. It is one of the many kinds of wild pigs found in different parts of the world.

National Zoblogical Garden



which the food can be brought up mouthful by mouthful to be chewed. The advantage of this stomach — and it is a very great advantage — is that its owner can gather food hastily and then retire to a place of safety while the masticating is being done. The ruminants are divided into the hornless ones (camels) and the horned ones. The horned ones are divided again — solid-horned (deer) and hollow-horned ones, which include the goats, sheep, antelope, and the buffalo-cattle-bison tribe. The giraffe has short solid horns and with the okapi makes a little group midway between the camels and the deer.

The sea cows are a water offshoot of the ruminants, their stomach being a modification of the ruminant type. They make up a small group of only seven species, four of them manatees and three of them dugongs. They are heavy animals, 8 or 10 feet in length. The forelimbs are flippers, the back limbs are wanting, and the tail is rounded and not notched like the tails of whales. The dugongs live along the shores of the Indian Ocean (most abundantly on the north coast of Australia) and the manatees in and near the mouths of the warmer rivers of America and western Africa. They feed on seaweed and water plants. A species formerly found along our Pacific coast is extinct.

Amazon manatees. The manatee is a water-living representative of the ruminants. The specimens shown are eating hay under water.



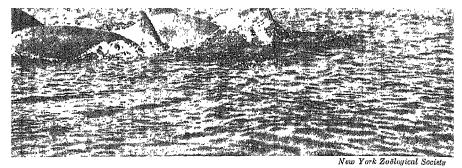


Ewing Gallonnay

Elephants, the giants among the living land mammals. They are extremely specialized in structure, and among the mammals they rank high in intelligence and character.

The elephants. The elephants are a highly specialized order. They are the largest of all the land mammals. At any one time they have no more than six teeth, two of which are the long tusks. The head is heavy and the neck short and thick, and in place of a movable head or hands the upper lip and nose are prolonged into a muscular, flexible trunk. They have five toes and the hoofs are little more than nails. In brain development they stand near the top — probably at the very top — of all the animals except man and some of the great apes. Their memory is proverbial and their intelligence high.

There are two species of living large elephants — the Asiatic and the African — and a pygmy species in Africa. The nearly related mastodon lived in our own country so recently that its skeletons, with the twigs the animals ate still undecayed, are found in bogs. There was also not long ago a hairy mammoth in Europe and Asia, as is shown by the tusks that were gathered and sold for ivory and by the finding of several actual bodies of them in Siberia, preserved in ice.



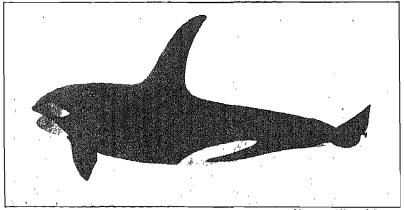
Backs and fins of porpoises. They are the smallest of the whales.

THE WHALES

The whales are a peculiar branch of the mammalian tree, a band of air breathers that went back into the sea and now never come to land. Originally they were probably river forms, but the sea was wide and they yielded to its appeal.

The whales are divided into two orders, the toothed whales and the whalebone or baleen whales. The whalebone whales are all large. Many of the toothed ones are of only moderate size.

The toothed whales. The smallest of the toothed whales are the porpoises (5 feet long) and the dolphins, which are longer and more slender. They eat fish and squids, go in shoals, are friendly and follow ships, and delight in jumping and playing in



American Museum of Natural History

The killer whale. These whales travel in bands and are the wolves of the sea.

PLACENTAL MAMMALS

the water. The narwhale of the colder seas is about 16 feet long and has a tusk of the upper jaw prolonged as a horn in front from 6 to 8 feet long. The killer whale, especially one species (*Orca gladiator*), attacks anything. It is found in all oceans, is from 15 to 20 feet long, spotted in color, and travels in rather small bands that are a terror to all larger kinds



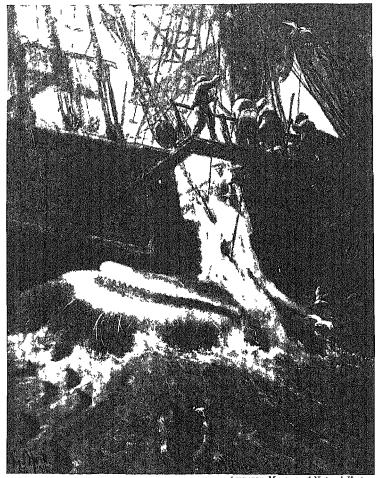
James Sauders

A dolphin. Note the fish-like form of these small whales. They are often thought of as fish and not as mammals.

of sea life. Killer whales are swift as torpedoes and with their strong jaws and ferocious teeth they not only seize fish but destroy immense numbers of seals and sea lions. They even attack the great whales, tearing at their sides and lips and inflicting mortal wounds.

The most important of the large toothed whales is the sperm whale, which may reach a length of 70 or 80 feet. It has a throat large enough to permit the swallowing of a man and its chief food is squids and fish. It is from this whale that sperm oil and ambergris are obtained.

The whalebone whales. The whalebone whales have enormous heads and huge mouths and from the roof of the mouth there hangs a great battery of plates made of an elastic material that is called whalebone or baleen. In many mammals the roof of the mouth is ridged, and in these whales the ridges are extended downward as sheets of whalebone. There may be 300 or 400 of these on each side and in some species the largest plates are 10 or 12 feet long and 8 feet wide. At the bottom these plates fray out into flexible but tough threads that lie on the tongue. The whalebone whales feed by rushing through the water with the mouth open and straining the water through their whalebone plates. In this way a whale is able to collect small organisms



American Museum of Natural History

Stripping the blubber from a giant whale. The men above are drawing the great sheets of fat up to the ship's deck. The water is full of sharks attracted to the feast. Read *Moby Duck* for detailed descriptions of scenes like this.

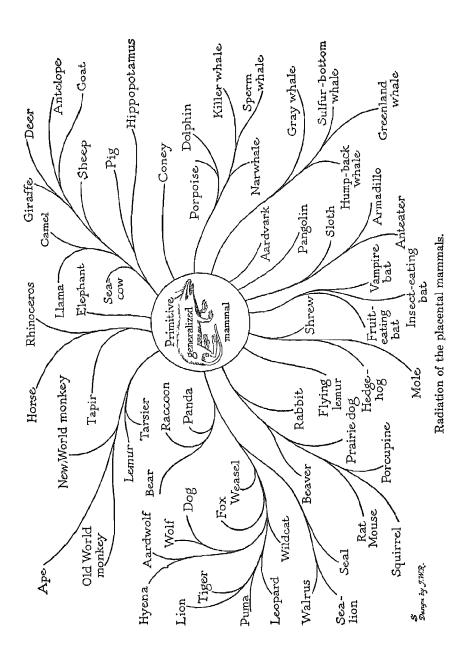
(copepods, pteropods) in great quantities — tons of them — and on these they subsist.

The mouth cavity in some species of baleen whales is 10 feet long and 12 feet wide, but the throat is small. One of the sulfurbottom whales is the largest of them — indeed, it is the largest of

all the mammals. The record for size is a length of 108 feet and an estimated weight of 300,000 pounds. No other known animal, ancient or modern, ever nearly equaled these great whales in size. It would of course be an impossibility for such animals to exist on land. A medium denser than air is necessary to help maintain their great weight. A large male of this species may yield nearly 300 barrels of oil and 3000 pounds of whalebone.

Whales are hunted for the oil that is secured from them and the baleen whales for the whalebone also. The invention of power-boats, harpoon guns, and explosive harpoons has now made their capture a comparatively easy matter and many kinds are becoming rare. The mothers come to warm and shallow waters when the young are born. As the baby nurses, the mother whale rocks from side to side so that the little one will have a chance to get air. Not much is known of their life histories, but it is believed that for such large animals they mature rapidly, reaching adult size in about 10 years. The meat of whales is good and in some countries is sold for human food. When we farm the sea the whales will probably be a part of the live stock we shall keep.

Of all mammals the whales are probably the most highly specialized. The forelimbs are turned into flippers and the hind ones are gone. The tail is forked and muscular like the tail of a fish, and the porpoises and dolphins have dorsal fins. The hairy coat in some kinds is reduced to two bristles on the upper lip. The large ones can dive to a depth of almost a mile and endure the awful pressure of that depth. They can remain immersed indefinitely in the icy waters of the polar seas and still keep up their They can remain under water for an hour, and the baleen whales have instead of teeth the complicated strainer apparatus that we have described. It has been a long, long time since the whale family turned its back on the land and it is amazing that it has had such success in the sea. If the toothed ones could develop gills so that they were freed from the necessity of remaining near the surface the sharks and fishes would probably be made to realize that in the sea as well as on the land the day of cold blood was gone.



Relationships of living placental mammals. None of the living orders of placental mammals are believed to be the ancestors of any of the other orders. The thought is rather that each order has arisen independently from a primitive early type; that the different orders do not stand one above the other. but each in its own special abilities and adaptations excels. burrowing the mole is supreme; the bat is best in the air; in running the dog, deer, and horse are in the first rank; in height the giraffe stands first; in length of nose the elephant has no rival; and in size the whale outranks all. The beaver cuts trees the fastest and builds the best dams. Is the beaver higher or lower than the lion, who stands in fearlessness above all the other beasts? In biology, differences do not necessarily mean superior or inferior rank.

You have only to examine the land life of today to see what a dominating position the mammals hold. They are in the warm tropics and they endure the cold of high mountains and of the far north. They are in the forests and on the plains. They are small as shrews and mice and as large as elephants and whales. Not only have they adapted themselves to all conditions of land life, but some of them, like the reptiles before them, have taken to the air and others have gone to the sea. In the mammals we find a truly remarkable example of the ability of life to adapt itself to the conditions under which it exists.

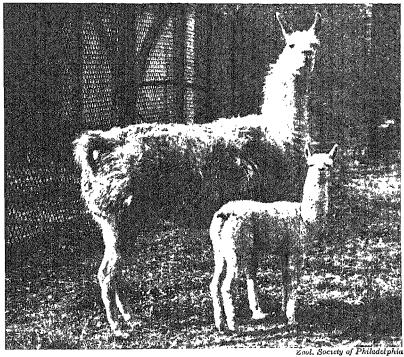
SUCCESS OF THE BIRDS AND MAMMALS

Birds and mammals have developed independently from the old reptile stock. They came to the land as the grasses and trees were covering it and providing an abundance of food for the support of animal life. They have radiated out in all possible directions and adapted themselves to every environment and all ways of living. Each important variation becomes a new center from which diverse types come into being, and the reptiles in large part have yielded their land domain to these newer forms.

One of the interesting points in connection with these airbreathing groups is their tendency to return to a water life. A very high percentage of birds are water birds, or they are waders or shore birds that live about the water. Mammals of many different orders have likewise gone to the water again for the food or the protection it affords. Studies of these aquatic forms have shown that they can endure a higher concentration of carbon dioxide in the blood than can the strictly land forms. We see the modifications of form that adapt these animals to a water life, but the even more important adaptations of the body chemistry are invisible to us.

Doubtless one chief factor in the success of the birds and mammals is the invisible quality that enables them to maintain a constant body temperature. On one frosty spring morning three lizards benumbed with the cold were picked up in a single farmyard. One had thrust its head into a tuft of grass, one lay on the well curb, one was within a yard of the woodpile that would have sheltered it. The evening before had been warm and the lizards had started out in search of food. Overtaken by the cold, they were unable to return to the security of their hiding places. From such occurrences it is easy to appreciate the disadvantages under which a cold-blooded land animal lives. A benumbed lizard or snake is helpless before its enemies. A great torpid dinosaur would be nothing but a meat supply for a little furry mammal active in spite of the cold.

SELF TEST AND EXERCISES



Guanacos



Maned wolf of Patagonia



Capybaras

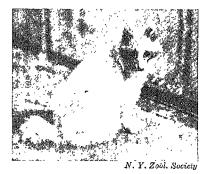
The South American animals shown above are different from their relatives in other parts of the world, and South America has many animals not found in other continents. Explain these facts.



Zool. Society of Philadelphia Lemur



Zool Society of Philadelphia Wisent



Raccoon dog of Japan



Giant anteater

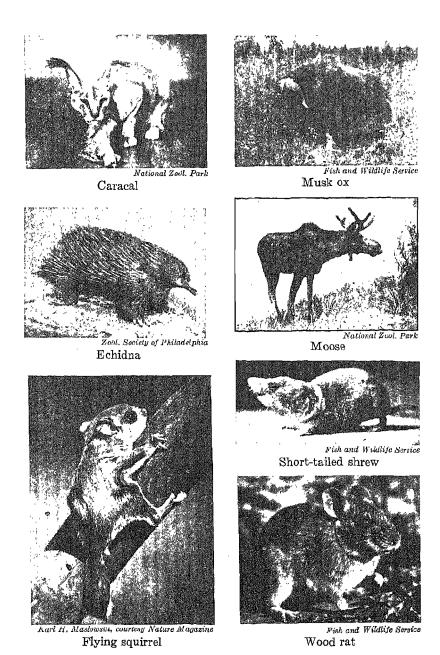


N. Y. Zoöl. Society
Young gorilla

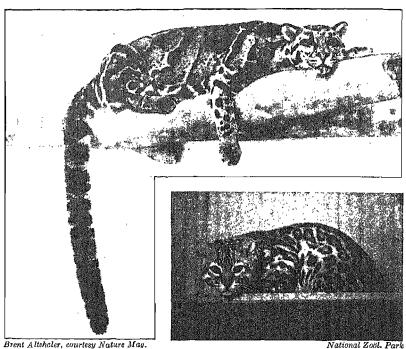


Weasel

Classify in as much detail as you can the mammals on this and the opposite page.

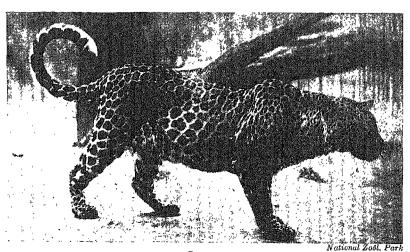


Name another animal closely related to each of the ones shown on this and the opposite page.



Brent Altsheler, courtesy Nature Mag.
Snow leopard

Ocelot



Jaguar

How do the mottled and spotted coats of these cats help make them inconspicuous?

UNIT COMPREHENSION TEST

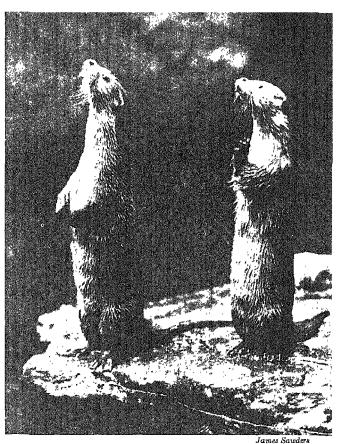
- A. Define a bird; a mammal. What are some of the structural adaptations of birds for flight? How are birds guided in their activities? Describe the structure of a bird's egg. Why is it necessary for birds to keep their eggs warm? What great new difficulties have birds met in recent times? What are the biological relationships of the birds?
- B. Name the three classes of feathers and describe each. What is meant by the moulting of a bird? What are some important characteristics of the bird body? of the limbs? What peculiarities are there in the alimentary tract? in the lungs? How is a bird physiologically adapted as a flying machine? What are other adaptations found among birds?
- C. What are the three subclasses of the mammals? Describe the platypus. How does it live? How are the young produced? What is an echidna like? How does it live? How does it incubate its eggs?
- D. What kind of animals are native to Australia? Describe the kangaroo and wallaby group. Describe the phalangers. On what do they feed? What kind of animals are the wombats and bandicoots? Name and describe three kinds of carnivorous marsupials. How many species of marsupial animals are found in Australia? Why are marsupials found in Australia and not in most of the rest of the world? What marsupials are found in the Americas?
- E. How many orders of the placental mammals belong to the claw-footed group? What are some animals that belong to the order insectivora? What are the characteristics of these animals? How many species of bats are there? What are some animals that are members of the rodent group? What animals belong to the order edentata? What are some of the different groups of the carnivora? What water animals belong to this order? Into what groups are the primates divided? What are the two main divisions of the hoofed animals? What are some animals that are odd-toed ungulates? some of the important even-toed ungulates? What is a ruminant? What advantage is there in the ruminant stomach plan? Name a number of families that belong to the ruminant order. What water forms have been developed by the ruminants? What are some of the characteristic features of the elephants? What close relatives of the elephants are extinct? Describe the toothed whales. How do the whalebone whales get their food? What is the size of the smallest and of the largest whales? What adaptations have the whales for a water life?

SUGGESTED ACTIVITIES AND APPLICATIONS

- 1. If any member of the class raises pigeons or has a special knowledge of canaries and their singing, let him make an oral report to the class and if possible exhibit one or more of the birds.
 - 2. Examine one of the larger bones of a bird. Why is it so light?
- 3. Open the body of a pigeon or a chicken and identify the principal internal organs. Either from your dissection or from a chart make a sketch of the alimentary canal and label its parts. Just back of the gizzard are little finger-like processes called *caeca* (singular *caecum*). These are hollow tubes. They secrete digestive juices into the intestine.
 - 4. Examine the feathers of a bird (e.g., pigeon, chicken).
- 5. Visit a museum and study the skeletons of birds. Visit a zoölogical garden and observe the different kinds of birds.
- 6. Begin keeping a record of the birds you see from day to day. List them in three groups permanent inhabitants, winter visitors from the North, and migrants from the South. Enter the dates on which the birds were observed.
- 7. When shrubs and trees are bare, make a collection of birds' nests. Birds are said to nest on four levels on the ground, in shrubs, in low trees, and in high trees. Keep a record of where each nest was found. The material of the nest and the way the nest is placed help identify the species by which it was made.
- 8. Make a list of the wild mammals that were found in your region before the settling of the country by white men. Make a second list of the mammals that are now living wild in your region. Have any new wild mammals been introduced?
- 9. Which order of the mammals would you say is the most valuable to man?

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UNIT]]

Jumes Bumbers

THE MAMMALIAN BODY

The bodies of all mammals are constructed on the same fundamental plan. The human body departs from the general type chiefly in its upright posture and in the great development of the cerebrum.

"The mammal remains the highest type of animal existence, and subsequent progress has been shown in the perfecting of that type."

JOHN FISKE

THE MAMMALIAN BODY TYPE

QUESTION FOR CLASS DISCUSSION

How can the independent development of high intelligence in so many orders of the mammals be accounted for?

THE bodies of mammals are constructed according to the general vertebrate plan, but in addition they have certain characteristic features of their own. Externally the mammals, far more than the birds, have retained the old dinosaur body form. Internally they have gone far beyond the birds in the development of new organs and in the perfecting of old ones. For walking and running on the land they are the best adapted of all animals. Some of them are splendidly fitted for life in the trees. The human body, except in its upright posture, is of a rather generalized type and much of our study will be based on it.

In the development of the cerebrum the mammals stand supreme, and in many different mammalian lines intelligence far beyond that found in any other animal group appears. The beaver, dog, grizzly bear, apes, horse, elephant, and Virginia deer are examples of animals that in their conduct display a high intelligence. According to tests made by psychologists the pig is the most intelligent of the domestic animals.

Problems in Unit 11

- 1 What are the important features of the mammalian body?
- 2 What are the chief organs connected with the nutrition of the mammalian body?
- 3 How are materials transported and distributed in the mammalian body?
- 4 What is the general plan of the mammalian nervous system?
- 5 What part do hormones have in regulating the mammalian body?

PROBLEM ONE

What Are the Important Features of the Mammalian Body?

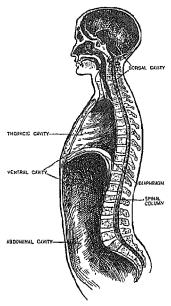
When we examine the body of a typical mammal we note that it has external ears, which the birds and reptiles lack. It has a nose, or snout. It has, except in some of the water-living forms, two pairs of strong limbs. It has a slender tail and characteristically the mammals have hair and mammary glands. Typically the number of digits (fingers or toes) is five.

Internally a mammal is characterized by having the ventral cavity divided by a membranous partition called the *diaphragm*. The heart and lungs lie in the *thoracic cavity* anterior to the

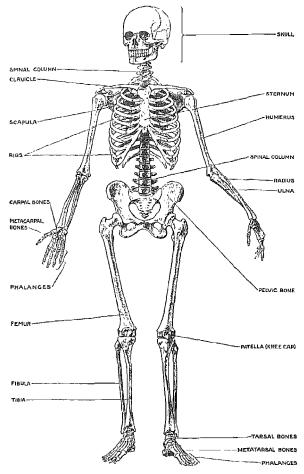
diaphragm. The stomach, intestine, liver, pancreas, kidneys, bladder, and other organs are packed in the abdominal cavity. At the top of the trachea the mammal has a larynx (lăr'ingks) and vocal cords. The location of the voice apparatus is different from its location in the birds (page 922).

Mammalian skeleton. The axial skeleton of a mammal consists of the spinal column, the skull, the ribs, and the sternum. The appendicular skeleton is made up of the bones of the limbs and of the pelvic and pectoral girdles.

In the very early stages of the mammalian embryo the skeleton is composed of cartilage. This is gradually replaced by bone until in the adult skeleton cartilage is found only as a covering on the ends of the

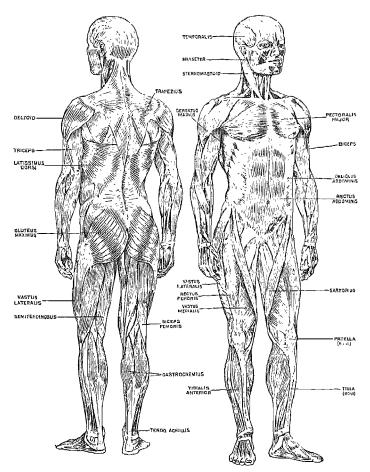


The cavities of the human body. The dorsal cavity cradles the spinal cord and brain. The ventral cavity contains a great collection of organs, as is shown on page 479.



The human skeleton. The skeleton supports the body, provides attachment for the muscles, and protects the more delicate parts.

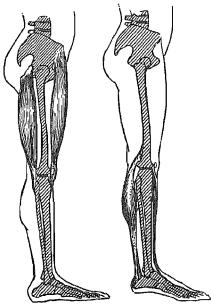
bones at the joints, as pads between the vertebrae, and at the ends of some of the ribs. Some children develop more rapidly than others and the physiological age of a child may differ from his chronological age (his age in years). One method of determining physiological age is to X-ray the wrists to see how far the change from cartilage to bone has progressed.



The outer muscles of the human body. There are more than five hundred muscles in the human body. They make up more than two fifths of the body weight.

The muscles. In their muscular system the mammals are highly developed. The great mass of lean meat in the body of a cow or a sheep is muscle. Two fifths of the weight of the human body is in the muscles. Fishes and crocodiles swim chiefly by bendings of the body and tail and their muscles are mainly body muscles. The land animals walk, run, climb, and carry on their

activities in general by the use of their limbs and in them the muscles that move the limbs are correspondingly well developed.



Illustrating how the muscles are attached to the skeleton and cause movement.

Study the illustrations on the preceding page. Most of the heavy muscles of the human body are attached to the limbs.

Muscles are divided into two great classes, voluntary and *involuntary*. The voluntary muscles are under the control of the will. We can contract them when we wish. You can raise your hand when you desire to do so because it is moved by voluntary muscles. Nearly all the voluntary muscles are attached to the skeleton, but a few of them are circular muscles about the openings of the body. The muscles around the eves and mouth

are examples of voluntary muscles that are not attached to the skeleton.

The involuntary muscles are not under the control of the will. They are found chiefly in the walls of the heart, blood vessels, and digestive tract and in other internal parts. The muscles of the mouth are voluntary — food can be held in the mouth without swallowing it. The muscles of the throat are involuntary — if food is once seized by them it is gone.

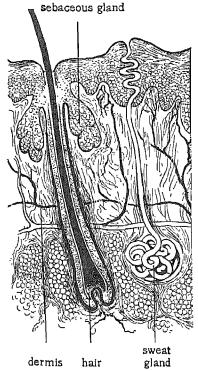
Body covering. The mammalian body is covered with a skin which is composed of an inner layer, the *dermis*, and an outer layer, the *epidermis*. The dermis is composed largely of tough connective-tissue fibers. The epidermal layer is a cellular one. In the deeper part of the epidermis the cells are alive, but

in its outer part they die and become dry scales, which are constantly lost from the surface of the skin. The deeper cells of the

epidermal layer continually grow and multiply and replace the cells that are lost.

The hairs are outgrowths of the epidermis. Each hair sits on a little bulb, or papilla, at the bottom of a pocket formed by the infolding of the epidermal layer. It grows by multiplication of the cells at its base. The sebaceous glands of the hair, the mammary glands, and the sweat glands develop from groups of epidermal cells that grow inward and arrange themselves in gland form.

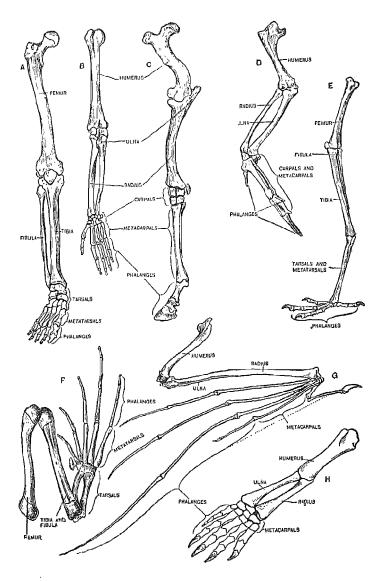
Modifications of epidermis. Modifications and outgrowths of the epidermis found in the mammalian group are claws, nails, hoofs, and horns. A few mammals have scaly plates developed and embedded in the skin. One of these, the pangolin



A section through the human skin.

of Africa, has horny scales all over the upper part of the body. Another, the armadillo, has an armor made by the union of its heavy epidermal plates. The birds show their kinship to the reptiles by the scales on their legs. Some of the mammals show it by their scaly skins. Even animals such as the rat and the beaver have scaly tails. The spines of the Echidna, hedgehog, and porcupine are formed by the fusion of a group of hairs.

Mammalian limbs. Although the limbs of mammals may be greatly modified to fit their use, there is a common pattern in them all. The illustration gives you the names of the bones in



Skeletons of vertebrate limbs, showing that they are all modifications of the same basal type. In the order in which they are lettered they are: human leg and arm; front leg of horse; wing and foot of bird; leg of frog; wing of bat; and leg of tortoise.

the different divisions of the limbs and the correspondences of the parts in the limbs of different animals. Note that the carpal (Latin *carpus*, wrist) and metacarpal bones are in the front limbs, and the tarsals (Latin *tarsus*, ankle) and metatarsals are in the back limbs. The greatest specialization of the limbs is likely to be in their extremities — the feet or the hands.

The plantigrade condition is regarded as the primitive one. In this condition all of a limb except the two upper sections (corresponding to the upper arm and forearm) are used in making the foot, and in walking the sole of the foot touches the ground. Examples of plantigrade animals are the opossum, shrew, bear, raccoon, and man. The carnivora walk on their toes and the hoofed animals walk either on their toes (camel, elephant) or on toenails which have grown into hoofs that enclose the toes.

Many examples of extreme modification and specialization are found in mammalian limbs. The foot of the horse consists of only the last segment of the middle digit enclosed in a hoof. In the wing of the bat the metacarpals and phalanges are extremely elongated. In the human hand the metacarpal region is widened and flattened, and the first digit (the thumb) is set back toward the wrist and made to work in opposition to the other

digits. In many of the herbivora (deer, giraffe, cattle, horse) the metacarpals are elongated and united, giving long, slender limbs adapted for running. What most persons regard as the knee in these animals corresponds to the ankle joint in man.

The head form of the primitive mammal was doubtless much like that shown on page 439. The jaws were projected into a slender muzzle and the forehead was low. The



Prints made by plantigrade feet. They are the tracks of a raccoon.

opossum shows much this same skull form today. In their projecting muzzles shrews, rats, wolves, and foxes resemble the primitive type.

Many mammals (cat, squirrel, monkey) have greatly shortened muzzles. In some (notably man) there is a building out of the forehead that along with the shortening of the jaws gives a face. Man has a much larger nose than most animals and he has developed on the front of the lower mandible a bony projection (chin) which gives prominence to the lower part of his face.

Position of eyes and ears. In some mammals (man, cat, dog) the eyes are set in the front of the head so that they focus together and look forward. In others (rabbit, squirrel, cow) the eyes are placed in the sides of the head, which makes the vision of the two eyes separate. Most animals which have the eyes on the sides of the head are among those that are preyed on by other animals. The arrangement may not be the best for examining small objects intently or for judging distance, but it enables an animal to see an enemy approaching from practically any direction.

Mammals' ears, too, vary in their position on the head and the external ears vary greatly in size. In most mammals they are movable and some animals by pointing their ears about are supposed to be able to judge rather accurately the direction of sounds. The position and size of the ears have an important effect on the appearance of the animal head and face. As you look at photographs of animals, try the effect of covering the ears.

Variation in necks and in head forms. In general the length of the neck among mammals is correlated with the animal's need in reaching for food. Most of the long-legged herbivorous animals have long necks. Where the food is brought to the mouth as in sloths and elephants the rule does not apply. Carnivorous forms need strength in their necks for killing, and in these the necks are short. In the pig and the hippopotamus the length of the neck is in harmony with length of limbs and the manner of procuring food. The number of vertebrae in the neck of a mammal is always seven. Greater length of neck is obtained

by lengthening the neck vertebrae and not by increasing their number.

The parts in which mammals are most variable are their limbs and their necks and heads. It is variations in these rather than in the shape of the trunk that give the different species their characteristic appearances and adapt them for their different ways of living. On photographs of mammals try covering the heads and limbs and note the general resemblance in body form. The water mammals, as an adaptation to their water environment, have departed most widely from the typical mammalian body shape and taken on the fish form.

PROBLEM TWO

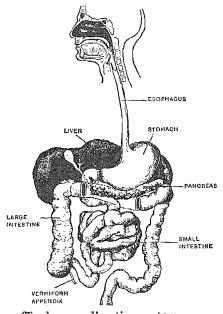
What Are the Chief Organs Connected with the Nutrition of the Mammalian Body?

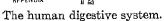
A mammal (like other animals) takes in food and oxygen. It digests the food, distributes it to the tissues, oxidizes it, and excretes the wastes. In this problem our subject is the organs and sets of organs that carry out these processes.

Mammalian digestive organs. The digestive organs include the alimentary canal and certain accessory organs of digestion. The principal parts of the alimentary canal are the mouth, pharynx (throat), esophagus, stomach, small intestine, and large intestine. The accessory organs of digestion are the teeth, the three pairs of salivary glands, the liver, and the pancreas. The function of the teeth is to grind up the food. The other accessory organs are glands that empty their secretions into the alimentary canal.

The alimentary canal is a long passageway in the body into which food is taken for digestion and absorption. It has in its walls muscles that contract on the food and force it onward. is lined throughout with mucous membrane, which is kept moist by sticky mucus. The mucus is secreted by glands in the wall of the canal and causes the food to move along more easily. As the food passes through the alimentary canal, digestive juices secretions from the digestive glands — are poured over it and mixed with it. Enzymes in the secretions then split up the food molecules into smaller ones that are soluble and can be absorbed into the blood. After digestion the food is taken into the blood and carried to the cells. The enzymes that do the work of digestion are built by the digestive glands and secreted by them. The wall of the small intestine is covered with small finger-like projections called *villi* (singular *villus*) that absorb the food.

All animal groups above the sponges have adopted the plan of taking foods into a cavity within the body for digestion. In doing this the mammals are only carrying on what Hydra began.



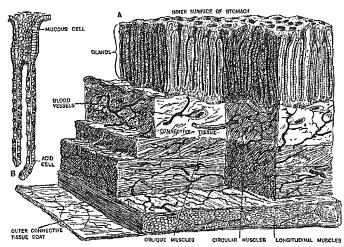




The salivary glands.



Glands and villi of the small intestine.



Section through the wall of the stomach, showing the glands and muscle layers. At the left is a single gland enlarged.

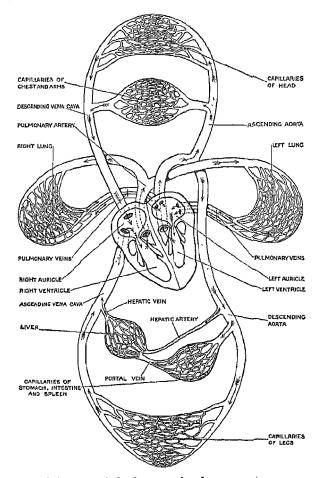
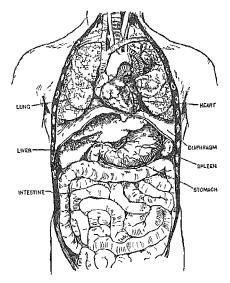
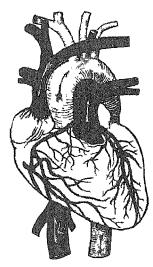


Diagram of the human circulatory system.

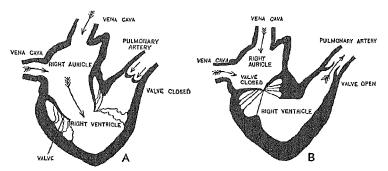
Circulatory system. The two sides of the mammalian heart are separated by a complete partition and the mammalian circulation is a double one. One side of the heart pumps the blood through the lungs. The other side sends it through the body. The diagram above shows the mammalian circulatory scheme. On the diagram trace the path of the blood on a complete journey through the body and lungs. The valves where the aorta and pulmonary artery lead out from the heart are



Organs in the ventral cavity, showing the position of the heart.



The heart and the bases of the great vessels.



Diagrams illustrating the working of the valves of the heart.



Valves at the base of the aorta.

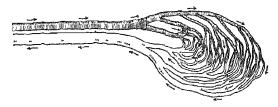


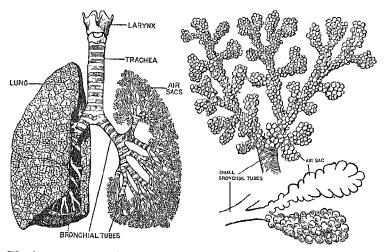
Diagram showing how the blood passes through the capillaries from an artery into a vein.

pocket-like structures, as is shown in the illustration. When the blood starts to flow backward into the heart, the pockets fill and swing outward, closing the opening.

The heart contains four chambers, the right and left auricles and the right and left ventricles. The auricles are mere thinwalled sacs that receive the blood from the veins. The ventricles have thick muscular walls that contract on the blood and force it through the body and the lungs. There are check valves in the heart so that when the contraction comes the blood can go only forward in the vessels.

In the mammals the blood circulates very rapidly. In man it requires on an average less than a minute for it to make the complete double circuit, which means that an amount of blood equal to all that is in the body passes through the body twice in a minute. In the tissues the tiny capillaries lie so close together that the finest needle point pressed into the tissue will break many of them.

Respiratory system. Mammals take in oxygen and give off carbon dioxide by means of the lungs. These are made up



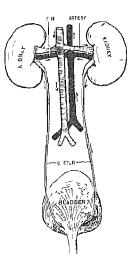
The lungs and the air sacs at the ends of the small bronchial tubes. In the lungs oxygen is absorbed into the blood and carbon dioxide is given off.

of air tubes, or *bronchi* (singular *bronchus*), that branch again and again until they end in tiny thin-walled sacs. There are millions of these little air sacs and through microscopic capillaries in their walls the blood shoots along in swift streams. In the

passage oxygen is absorbed by the blood from the air in the sacs and carbon dioxide is given off.

Breathing is carried out by movements of the diaphragm and ribs. Notice in yourself how this is done. When the diaphragm is pulled down and the ribs are raised, the size of the thoracic cavity is increased and air enters the lungs. When the diaphragm rises and the ribs sink, air is expelled.

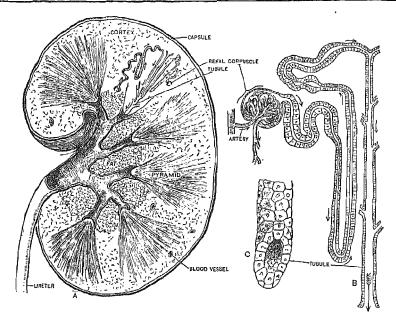
The kidneys. All animals of any size have organs which excrete from the body waste materials. The worms have nephridia; there are excretory glands (called "green glands") at the bases of the antennae (feelers) of a crayfish; in the insect a multitude of fine tubules (Malpighian



The kidneys and bladder seen from behind.

tubules) remove the protein wastes from the blood and excrete them into the intestine. In the vertebrates the corresponding organs are the kidneys. They are two in number and are fastened to the dorsal wall of the abdominal cavity. In the different classes of vertebrates the kidneys differ greatly in appearance and it is to the mammalian kidney that the description given below specifically applies.

The illustration on the next page shows the form and structure of a kidney. It is made up of little tubules, each of which takes from the blood water and waste materials that are in solution in the water. All the tubules of a kidney empty into a single duct, the *ureter* (\u00fc-r\u00e4'\u00e4re'), which carries the secretion from the kidney to the bladder. Study the diagram of a kidney tubule. Note that the inner end of each branch is a little sac in which a tuft of capillaries embeds itself. The water and waste materials



A is a longitudinal section of a kidney, showing how the kidney tubules empty into the branches of the ureter. B is a kidney tubule and capillary tuft (corpuscle) enlarged. Fluids filter out of the capillaries in the corpuscle and flow into the tubules. In the long, winding passage down the tubules, the fluid is concentrated by reabsorption of water. C is a small portion of a tubule, showing how the walls are built of cells.

of the blood pass from the capillaries into the tubule and thus are removed from the blood.

The function of the kidneys is to remove from the body excess salts and protein wastes. They excrete from the body substances that would be harmful in too great concentration.

Regulation of the body temperature. Physiologically, the great advance of the birds and mammals lies in the fact that they are able to regulate their body temperatures so that their entire existence and all their activities can be keyed to a warm-blooded life. How is a constant body warmth maintained?

First of all, there must be sufficient heat produced at all times to keep up the body temperature. A warm-blooded animal must be able to find a constant supply of food, which it must oxidize rapidly enough to replace heat as fast as it is lost. The greatest seat of oxidation is the muscles, and by exercising these or by holding them at greater tension oxidation can be increased. Exercise is like opening the draughts on a boiler. In very violent exercise the body produces three or four times as much heat as when it is at rest.

Second, there must be a way of retaining the heat. For this purpose we use clothing. Birds have feathers and most of the mammals have hair. Many mammals, especially water mammals, and cold-region birds have also an insulating layer of fat beneath the skin. In the temperate and arctic regions of the earth a heat-retaining covering of some kind is absolutely necessary for a small warm-blooded animal. A chickadee or a wood-pecker could not last an hour in the winter cold without its coat, and until feathers and hair were evolved a small warm-blooded animal outside the tropics was not possible.

Third, a constant-temperature animal must have a thermostat — an arrangement for regulating the heat; for the temperature must be kept from rising too high as well as from falling too low. Our own normal body temperature is 98.6° F., and to maintain it at this exact point requires a delicate and efficient regulator. In our bodies this is provided through the sweat glands and the circulatory system. When the temperature rises too high, the sweat glands pour out perspiration on the skin, and by the evaporation of the perspiration the body is cooled. Also, when the temperature rises the vessels in the skin expand and allow the blood to come to the surface, where the heat is lost. When the body temperature falls, the skin remains dry and the vessels in it contract and keep the blood and heat within.

Birds and mammals that have few or no sweat glands, such as dogs, cats, and sheep, get rid of surplus heat by rapid breathing. They "pant" when they are hot, and from their lungs water is evaporated. Except when the atmosphere is extremely hot, heat is lost also by warming the air that is taken in and exhaled. The feathers of birds and the thick coats of many mammals

would render ineffective a cooling system composed of sweat glands and an intermittent switching on and off of the blood supply of the skin.

All the birds maintain a constant high temperature, but the mammals are not yet fully committed to the hot-blooded way. Bears, woodchucks, ground squirrels, bats, raccoons, skunks, and many other mammals have periods of hibernation. A species of monkey that lives in the northern part of Japan hibernates. Even human beings can go into a hibernating condition, as has been found out in hospitals by packing patients in ice and putting them to sleep for several days. In these human experiments the body temperatures drop to 90° or 91°, and after the sleep has ended there is no memory of it.

The greatest internal variation in mammals is in their digestive tracts. These differ according to the food they eat. The carnivorous kinds have short intestines. The herbivorous ones have very long intestines in which great quantities of coarse food can be retained as digestion goes on. The stomach serves not only as a digestive organ but also as a storehouse into which enough food can be taken at once to support the body for some time. The ruminant stomach is a special adaptation to the coarse and bulky food upon which the ruminants subsist.

PROBLEM THREE

How Are Materials Transported and Distributed in the Mammalian Body?

When cells live in a large colony, food and oxygen must be carried to each cell and the cell wastes be removed. We shall in this problem make a more exact study of how in the mammalian body this is done. We shall, as in the preceding problem, use the human body as a type mammalian form.

Blood vessels and blood pressure. The blood is pumped out from the heart through the arteries. It passes out

into the small arteries and on into the minute capillaries. Then it is collected into the veins and brought back to the heart.

The walls of the arteries have a thick muscular layer and they are





Cross section of an artery and a vein. The arterial walls are more muscular and more elastic.

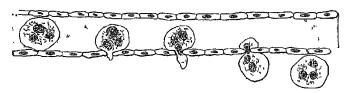
elastic. When the heart beats and forces onward an additional quantity of blood a wave of pressure runs out along the arteries, which you can feel as the pulse. The pressure in the arteries forces the blood onward through the capillaries and back to the heart through the veins. If the heart pumps feebly and the muscles of the small arteries are relaxed the pressure is low. If the heart pumps vigorously and the arteries contract and so cut down the blood flow into the capillaries the pressure is high. Obesity tends to increase blood pressure by making it harder for the blood to pass through the capillaries of the fat-laden tissues.

The blood. The blood is composed of a liquid part, the plasma, and of corpuscles that float in the plasma. Dissolved in the plasma are foods, salts, and other materials used by the cells, and wastes from the cells. The corpuscles are cells living free in the plasma. They are of two kinds, white corpuscles and red

corpuscles. Normally there are about 8000 white corpuscles and 5,000,000 red ones in a cubic millimeter of blood — an amount that would form a drop about the size of the head of a pin.

When blood clots, white threads composed of a material called *fibrin* form in the plasma. These enmesh the corpuscles and contract on them, forming with the corpuscles the semisolid clot. The yellowish liquid — the remaining part of the plasma — is called *blood serum* (plural, *sera*).

The white corpuscles. The white corpuscles are pale in color. Each is a soft, sticky little particle of protoplasm with no cell wall about it. More than any other of the body cells the white corpuscles resemble independent little one-celled animals. They are of several different types and are classified in two principal groups, the *lymphocytes* (lim'fo-sits) and the *leucocytes*. The lymphocytes have little power of motion, but the leucocytes can creep about like little amebas. They often escape from the capillaries by crawling out between the cells of the capillary walls. They collect where there is injured or diseased tissue and engulf and digest matter that is foreign or hurtful to the body. They are one of the principal defenses of the body against germs (page 595).



A white blood corpuscle escaping from a capillary. During inflammation, these cells migrate in great numbers to the affected area.

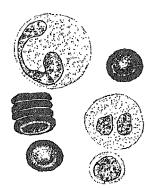
In some infections the number of white corpuscles of certain types increase in the blood. Physicians often make a count of the different types of blood corpuscles as an aid to the diagnosis of a disease.

The red corpuscles. The red corpuscles are highly specialized cells. They are formed chiefly in the marrow of the

bones. Here some of the cells lose their nuclei, take on the shape of corpuscles, and float away in the blood stream as red corpuscles.

Their average life in the blood is only about two weeks. It has been estimated that in the human body about fourteen billions of them die every day and as many new ones are formed. They are broken up chiefly in the spleen and part of the disintegrated materials from them is excreted as the coloring matter of the bile.

The special function of the red corpuscles is the carrying of oxygen. They have within them the iron-containing compound, hemoglobin, which forms a



White and red blood corpuscles.

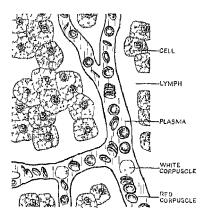
loose compound with oxygen. When the red corpuscles pass through the capillaries of the lungs each hemoglobin molecule takes on four atoms of oxygen. Then when the corpuscle goes out into the capillaries among the cells the hemoglobin gives up its oxygen to the cells. When the hemoglobin unites with oxygen the compound formed (oxyhemoglobin) is bright red in color; it is this compound that gives the red color to the blood. The blood in the veins of your forearm has lost its oxygen to the tissues and you can see that it has a dark color. Carbon dioxide is carried in the blood in solution. It does not unite with the hemoglobin of the corpuscles as the oxygen does.

Human beings are divided into four groups on the basis of differences in their red corpuscles. For some reason not understood the corpuscles of a person of one group will go to pieces if they are transferred to the vessels of a person of a different group. Before a blood transfusion it is necessary to know that the giver of the blood is of the same group as the person who receives it.

The lymph. The blood plasma soaks through the thin walls of the capillaries and passes out among the body cells. After the plasma is outside the capillaries it is called *lymph*. The lymph surrounds all the cells in the body; it fills all the little

spaces between the cells. A fresh supply of lymph is constantly escaping from the blood and the amount of lymph in the body is several times as great as the amount of blood.

The function of the lymph is to receive food and oxygen from the blood and pass them on to the cells, and to receive the wastes from



The cells are bathed in lymph. This is blood plasma that has escaped from the capillaries.

the cells and pass them to the blood. The cells, except the blood corpuscles, lie outside the blood capillaries. The food and oxygen must pass out of the blood capillaries before they can reach the cells. This the food and oxygen do by passing out through the capillary walls into the lymph and then through the lymph to the cells.

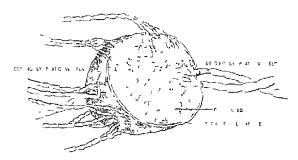
In the same way the wastes reach the blood by first passing out of the cells into the lymph. The lymph is therefore a middle-

man between the cells and the blood. It is the lymph and not the blood that comes in contact with the cells and supplies their needs.

The lymphatic vessels. Since the plasma is continually escaping from the blood capillaries there must be some way of carrying the lymph away from among the cells; otherwise too much lymph would collect in the tissues and the body would become swelled with liquid. The lymph cannot go back into the blood capillaries against the current of escaping plasma; so there is another system of vessels to drain it away from among the cells. The vessels that do this are called the *lymphatic vessels*. Their function is to collect the lymph from among the tissues and carry it again to the blood. The lymph flows into the lymph capillaries, which form a thick network among the cells. The capillaries unite and form larger vessels, which finally empty by two chief vessels into the blood.

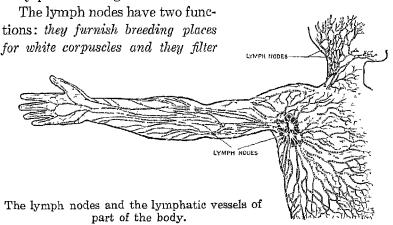
The lymph nodes. Scattered through the body are many white bodies called *lymph nodes*. There are six or seven hundred of them in the body, large enough to be seen without a microscope. They vary from microscopic size to the size of an almond. Popularly these nodes are known as "lymphatic glands."

A lymph node has a connective-tissue capsule and is filled with white corpuscles. The lymphatic vessels pour the lymph



A lymph node, showing the vessels leading to and away from it. It functions as a strainer.

into these nodes, where it filters through among the corpuscles in the node much as water filters through sand grains. After passing through the node the lymph is taken up and carried on by other lymphatic vessels. The lymph from many parts of the body passes through several nodes before it reaches the blood.



out disease germs that get in among the cells and are taken up by the lymphatic capillaries. By their action as filters the nodes keep germs from getting into the blood and being carried all through the body. Many diseases are caused by germs that live and grow among the cells. Some of these germs are taken up by the lymph capillaries and carried into the lymph nodes. The nodes stop the germs and thus the germs are kept from getting into the blood and being carried all through the body.

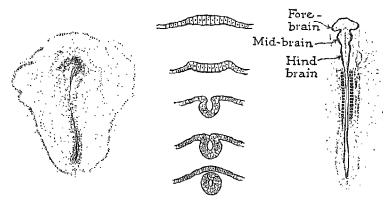
Sometimes infected lymph nodes can be felt as hard bodies under the skin in the neck or armpit. When the tonsils are infected and in early tuberculosis, the nodes about the trachea are often enlarged. In cancer, cells and small groups of cells are carried into the lymph nodes that receive the lymph from the malignant tissue, and set up their growth there. It is impossible to treat the disease successfully after the cancer cells have reached the lymph nodes that lie deep in the body. It is important, therefore, that a physician be consulted at the earliest possible moment.

In any mammal the distributory mechanism is essentially the same as it is in man, and in vertebrates other than mammals the differences are chiefly in details. The system is simple in principle but complicated in its exact workings. Its efficiency is demonstrated by the fact that it enables billions of cells to live crowded together, as they are in the body of one of the larger animals.

PROBLEM FOUR

What Is the General Plan of the Mammalian Nervous System?

In the mammalian embryo (as in the embryos of other vertebrates) the nervous system is developed from a long fold in the ectoderm along the back. A depression or trough comes in the back; the edges of the trough grow up and come together; thus a cylinder of ectodermal tissue is buried in the embryo's back.



At the left is a view of part of a chick embryo after 24 hours of incubation. It shows the streak of tissue along the back which develops into the spinal cord.

The center drawing shows in a diagrammatic way how the nerve cord is buried.

At the right is a portion of a 37-hour embryo, showing the divisions of the developing brain. The dark bodies are segments or blocks of mesodermal tissue from which the bones and muscles of the trunk are formed.

This rod of buried tissue becomes the spinal cord; its front end widens and thickens and becomes the brain. Within it the cells become specialized. Nerves grow out from the brain and cord and penetrate all the tissues to the most distant body parts. The great nervous system thus developed is the controller of the body. It puts all the body parts into communication with each other and coördinates their activities. The nervous system has two main divisions, the *central nervous system* and the *autonomic system*. Each of these with its functions will be considered after a brief study of the nerve tissues of which they are composed.

ELEMENTS OF THE NERVOUS SYSTEM

The great feature of nerve tissue is the extensive branching of the cells. The cells themselves are located in the spinal cord



A neuron, consisting of a nerve cell and a nerve fiber.

and brain or in small groups (ganglia) in the internal parts of the body, but the branches of the cells are so long that they extend to the skin, muscles, and other tissues and organs everywhere. The nerve impulses that pass to and from the different body parts travel along branches of the nerve cells.

Neurons and nerve fibers. The unit out of which the nervous system is built is the neuron. The typical neuron is a cell with no wall, a large nucleus, and the cytoplasm drawn out into long branches. In some neurons the strands of cytoplasm radiate out in all directions in fine branching arms. In others, in addition to branches of this kind there is one very long branch, the axon. Some nerve cells have no branches except an axon that divides in a T-shaped manner, as indicated in

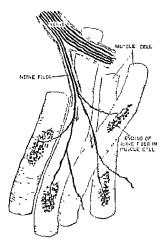
the illustration on page 726. The body of a nerve cell with all its branches taken together is a neuron.

The long axon of a neuron with a covering developed about it is called a *nerve fiber*. In some fibers there is in the covering of the axon a fatty layer that gives to the fiber a white appearance. Other fibers have only a thin transparent sheath about the axon and these fibers are gray. The nerve impulse is carried in the axon, which forms the center of the fiber.

Afferent and efferent fibers. Some nerve fibers carry inward-traveling impulses which give rise to sensations. Im-

pulses from the skin, for example, when they are received in the brain cause sensations of touch, temperature, or pain. Impulses from the eye and the ear give sensations of sight and sound.





At the left is a section of the retina of the eye. The long cells are sensory nerve cells whose inner (lower) ends are buried in pigment. When light affects the pigment, the nerve cells are stimulated and transmit an impulse to the brain.

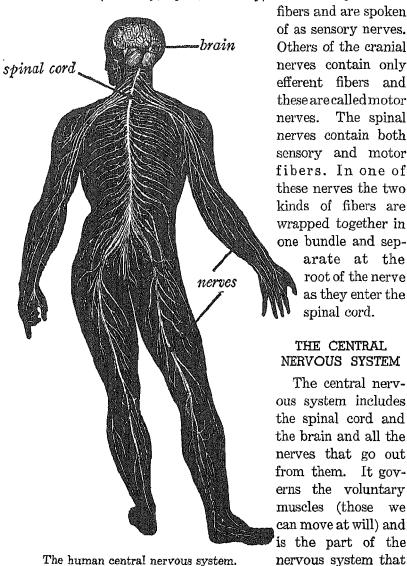
At the right are nerve fibers ending in muscle cells. These are motor nerve endings.

Nerve fibers that carry impulses inward to the nerve centers are called *afferent* (Latin ad, to, + fero, carry) fibers. They are also called **sensory** fibers.

Other fibers carry impulses outward that cause muscles to contract or glands to secrete. These fibers are called *efferent* (Latin *ex*, out, + *fero*, carry) fibers. Sometimes they are called *motor* fibers because most of them go to muscles and the impulses from them cause movement.

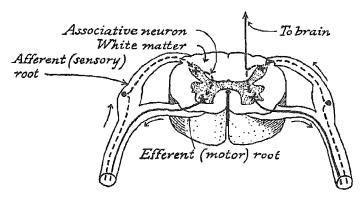
Nerves. The fibers that connect the nerve centers with the various parts of the body are bound together in bundles that are called *nerves*. These go to all parts of the body and break into finer and finer branches until they end in individual nerve fibers or even branches of fibers.

Twelve pairs of nerves that arise from the lower surface of the mammalian brain are called cranial nerves. Thirty-one pairs that arise from the spinal cord are called spinal nerves. Some of the cranial nerves (olfactory, optic, auditory) contain only afferent



The human central nervous system.

has to do with sensation and mind. Through the various classes of vertebrates the cord is quite uniform in structure and function. It is in the brain that differences in the various classes are found.



Cross section of the spinal cord, showing a pair of spinal nerves arising from it. The spinal cord coördinates and transmits nerve impulses.

Spinal cord. The spinal cord has an enlargement for each segment of the body and sends out a pair of nerves to each segment. Each enlargement, or segment, of the cord is connected by nerve fibers to its own particular body segment and also with the other parts of the cord and the brain. The inner part of the cord is gray matter. This matter is made up of nerve cells and of gray fibers that connect different parts of the cord together. The outside of the cord is white matter — white nerve fibers that connect the cord and the brain. These fibers connect with the interior gray matter of the cord. Through them impulses are passed on up from the cord to the brain and down from the brain into the cord and on out to the muscles.

Functions of spinal cord. One function of the spinal cord is to serve as a controlling center for the parts of the body that it supplies with nerves. If the brain of a frog is destroyed and after this its toe is pinched, the frog will pull the foot away. If the skin of the back is pinched with a pair of forceps, the frog will put up a foot and push the forceps away. The spinal cord

not only receives impulses from the different fibers of the nerves and turns them back down through the efferent fibers, but without any help from the brain it coördinates these outgoing impulses. A brainless frog responding to stimuli makes movements that require the use of more than one muscle, or perhaps the use of even more than one leg. The cord not only reflects the incoming impulses back to the muscles but arranges them in the right order of time and gives them the right degrees of intensity so that each muscle contracts when and as much as it should.

A second function of the spinal cord is to transmit impulses to and from the brain. Pinch your finger — the impulse will go into the cord and then on up to the brain, resulting in the feeling of touch or pain. If you decide to lift your hand the impulse starts in the brain, goes down the cord, and out to the muscles of the arm. The spinal cord is a transmitter of impulses below the head and the brain. If it is cut the part of the body below the cut is paralyzed and all sensation in that part is lost.

Development of vertebrate brain. In the little provertebrate Amphioxus (page 375) there is no brain. The nerve cord simply runs forward to the front of the body, where the olfactory organs and eyes are attached to it. In the lowest true vertebrates, however, the development of the brain begins and this development continues up to man. Study the series of brains shown on page 377. In the frog's brain there can be distinguished the three primary divisions, the forebrain, midbrain, and hindbrain. The small cerebral hemispheres are outgrowths of the forebrain. The optic lobes arise from the midbrain. The cerebellum is a single upgrowth from the hindbrain.

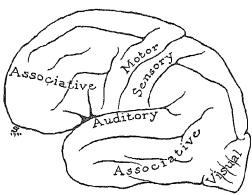
Note that as we ascend through the classes of vertebrates the optic lobes decrease rather than increase in size, but that the cerebellum and the cerebrum show a constant increase. In the birds and especially in the mammals the cerebellum and the cerebrum entirely overgrow and cover the other parts of the brain.

This development of new parts gives to the higher vertebrates a two-story brain. There is a lower portion (thalamus and hypothalamus, page 375) that contains masses of nerve cells called the *basal ganglia*. This corresponds to the whole brain in the primitive vertebrates. Above is the new brain, developed by the great increase in size of the cerebellum and the cerebrum. All vertebrates have the old brain. The higher we rise in the vertebrate scale the greater increase do we find in the size and complexity of the new one. The higher mammals are especially noted for the development of the cerebrum. In the human brain the cerebral hemispheres form a mass that overlies all the rest of the brain and fills all the upper and outer part of the enormously enlarged cranial cavity. Our study of the brain will have special application to the brains of the higher mammals and especially to the brain of man.

Function of lower brain. The lower brain is an expansion of the fore part of the spinal cord and it carries on the same functions as the cord. It governs the muscles of the head and neck which it supplies with nerves; also it is a pathway for impulses passing to and fro from the higher centers of the brain. It is especially important because the nerves of smell, sight, taste, and hearing have their origin in it.

The masses of nerve cells (basal ganglia) in the lower part of the cerebrum and midbrain have additional important functions. They are intimately connected with the internal organs of the body and act almost like independent brains in their control of these organs. Through the autonomic nervous system and the basal ganglia the internal organs are regulated without the cerebrum's knowing what is being done. Moreover, as we have noted, the centers for the instincts and the emotions are believed to be in the hypothalamus. It is in the midbrain, down below the level of intelligence, that we feel anger, fear, love, and hate. Buried in this old part of the brain structure are the mysterious instincts that drive men and animals to act as they do.

Function of cerebellum. The cerebellum is supposed to help in keeping the muscles at the right tension and in maintaining equilibrium. If it is injured in a bird, the bird cannot keep its balance in flying. An animal or man with an injured cerebellum staggers in walking. When the cerebellum is damaged the muscles seem to hang slack (lack "tonus") and there is not a prompt response when the body starts to fall. The cerebellum is in close connection with the semicircular canals of the ear; it seems to keep a general superintendency over the tension of the muscles and to coördinate the movements of those by which



A diagram of the cerebrum, indicating the function of different areas of the cortex.

equilibrium is maintained. It is particularly well developed in birds.

The cerebrum. The cerebrum (ser'e-brum) is the part of the brain in which man especially excels. Over the convoluted (wrinkled) surface of the hemispheres is a cortex composed of a thick layer of nerve cells

(gray matter). Within the cerebrum are great bands and tracts of fibers connecting the two hemispheres, connecting the front and back parts of each hemisphere, connecting portions of the cortex with the basal ganglia and with the cerebellum and the spinal cord. There are special motor areas that are connected through tracts of fibers with the muscles of different parts of the body; there are other areas to which the impulses from the organs of sight, hearing, smell, and taste are referred; and there are great areas (called associative areas) that seem to have no direct connection with any body part but may be concerned with intellectual processes or the coördination of impulses that are sent out. It is estimated that in the two hemispheres of the human cerebrum there are twenty-two billion neurons, and the complexity of this organ is beyond anything that the organ itself can conceive.

In some way in this maze of nerve cells and fibers thought and

consciousness are evolved. Somehow in it there lurk the mental ghosts we know as memories. In some way in the cerebrum sensations are experienced. In it or of it or in some way connected with it is that which the old philosophers called the *ego*, the conscious self.

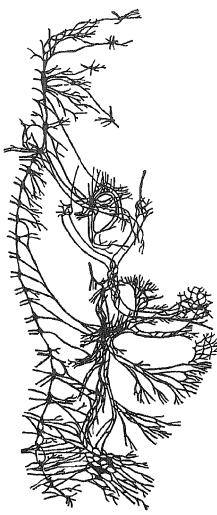
Function of cerebrum. The function of the cerebrum is to bring intelligence to the control of conduct. It directs actions to distant ends. It is man's cerebrum that causes him to respond to nightfall, not by going to bed as the chickens do, but by inventing a generator, making an electric lamp, and having artificial light in his home. We have in our lives to a very marked degree passed beyond the stage of unconscious action through the lower nerve centers; in man the higher nerve centers have taken control.

Fortunately it is not necessary for the conscious intelligence to oversee every little act of the daily life. The cerebrum is "changed by use," so that when an act that brings a satisfactory result has been carried out a number of times there is a tendency to repeat it without thought. These learned responses we call habits. A habit is formed by some change taking place in the cerebrum that causes impulses to follow certain courses through it, without thought and without the direction of the intelligence. If the cerebral cortex of an animal is removed, all its habits with everything else it has learned are wiped out.

THE AUTONOMIC NERVOUS SYSTEM

The word "autonomic" is from the Greek autos, self, + nomos, law. The name of the autonomic nervous system implies that it is a law unto itself, a self-working system, independent both of the outside world and of the cerebrum. In a large measure in its ordinary operations this is true. Usually it regulates the internal organs without our even knowing that the regulating is being done. The autonomic system includes the nerves of the internal organs and glands.

Centers and divisions of autonomic system. In the development of the nervous system groups of cells are pinched off from the central nerve cord and moved out among the other tissues. These become the ganglia in which are located the cells of the autonomic system. The chief centers of the system are two chains of ganglia, one on each side of the spinal column, in the back wall of the body cavity. In addition, it includes a



The human autonomic nervous system.

number of other scattered ganglia; also fibers that connect the ganglia with each other, with the organs the system controls, and with the spinal cord and the brain.

The central part of the autonomic system — the part that is concerned with the control of the heart, stomach, intestines, liver — is called the sympathetic system. The upper and lower parts taken together make up the parasympathetic system. The sympathetic system is intimately connected with violent emotional disturbances and its condition probably has much to do with what we call nervous stability and instability.

Function of autonomic system. The autonomic system regulates the involuntary muscles (those not under the control of the will) and the glands of the body. This gives it control over the muscles of the heart, of the blood vessels, and of

the muscles in the walls of the stomach and intestine and over such organs as the salivary glands, pancreas, liver, kidneys, sweat glands, and the glands of the stomach and intestinal walls.

Ordinarily we are not conscious of the workings of this system, but it is not independent of the central system. In origin it is a subdivision of the central system; impulses from the central system can be sent into it and impulses from it are received into the spinal cord and brain. Under usual conditions the impulses from the afferent autonomic fibers do not make their way into the field of consciousness, but if they are very strong they may do so. Severe contractions (cramps) of the stomach start impulses that register in the cerebrum as pain.

From our study the general plan of the mammalian nervous system becomes evident. It consists of an elongated central axis — cord and brain — and of branches extending out from this axis to all the body parts. The system is a connector of the body parts. It puts them all into communication with each other and coördinates their activities. The internal parts are regulated in large part through the autonomic system and the cell masses (basal ganglia) of the lower brain. The voluntary muscles, which must act to bring the body into adjustment with the outside world, are under the control of the cerebral cortex, where the intelligence resides.

PROBLEM FIVE

What Part Do Hormones Have in Regulating the Mammalian Body?

Animals are subject to changes in temperature and to the influence of light and darkness. They have periods of muscular exercise and of rest. Most animals and birds in the wild have breeding seasons and times of sexual inactivity. There are processes of growth and tissue differentiation in early life that are not continued after maturity is reached. Life is a thing of constant change, and because of this fact the living machine cannot be set to operate in a certain way and then left to go on indefinitely. There must be continuous adjustment of the chemical processes of the organism to its internal needs and impulses and to the external conditions of its life.

This adjustment is effected in large part through the hormones that are produced by the endocrine glands. In former units we have referred to these substances and to their effects in both animals and plants (page 28). The animal hormones have been investigated chiefly in connection with human medicine and our discussion of them will apply especially to man.

Hormones and their importance. A hormone has been defined as a substance that is manufactured in one organ or part of a plant or animal body and that has a definite effect on some other part or parts. In general the function of hormones is to control the chemical processes of the organism. In some cases they determine whether the process shall be carried on. In other cases they control the rate of the process. They affect not only the physical workings of the body but also the emotions and instincts, and through these influence the actions and the mental state.

The hormones, like the vitamins, belong to no one class of chemical compounds and why these particular substances are needed in the animal body we do not know. Of their importance as regulators of the body processes there can be no doubt. Only

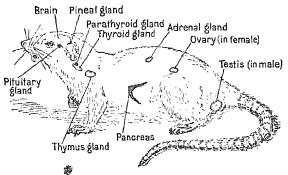


Diagram showing the location of the important endocrine glands of a mammal.

when the endocrine glands are working properly and each of the hormones is present in the right amounts do the body parts and organs work together in harmony and enable the body to make the adjustments necessary for its welfare.

Endocrine glands. In man and other vertebrates the hormones are manufactured in a set of organs that are known as endocrine glands. These glands are spoken of as the "ductless glands" because they have no ducts. Their secretions simply pass out of the gland cells directly into the blood. The known endocrine glands include the thyroid, pituitary, adrenal (ădrē'nal), thymus, and pineal (pĭn'e-al) glands, the sex glands, and certain little nodes of tissue (Islands of Langerhans) in the pancreas that secrete insulin. The liver and the cells of the sympathetic nervous system also produce hormones and hence function as endocrine glands.

THE THYROID GLAND

The thyroid is the largest of the endocrine glands and its function is the best known. It lies against the sides of the lower part of the neck and consists of two flat lobes joined across the front. It is richly provided with blood vessels and lymphatics and is larger in the female than in the male. The thyroid secretes a hormone, thyroxin, which increases the rate at which the food is oxidized within the body. If too much thyroxin

is produced the food burns too rapidly in the body; if not enough is produced the food burns more slowly than is normal.

Basal metabolism test. A test called the basal metabolism test is used to measure the activity of the thyroid gland. By this test the rapidity with which food is being oxidized is determined. The person is made to inhale pure oxygen for a definite time, and the amount of the oxygen that is used in the body is measured. From this it is known how much oxygen is being used in the burning of food, and this amount is compared with the amount that is normal for the height, weight, age, and sex of the person. If the person is using less oxygen than normal it is judged that there is a deficiency in the amount of thyroid secretion — a condition of hypothyroidism exists. If more oxygen than is normal is used the food is oxidizing too rapidly — a condition of hyperthyroidism exists.

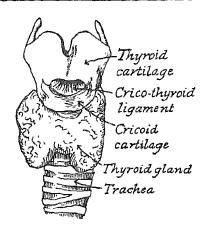
Eating or exercise of the muscles increases the body metabolism; so the test is made before food is taken in the morning and the person is required to lie relaxed and quiet for a half hour before it begins.

Hypothyroidism. For the final diagnosis of hypothyroidism and hyperthyroidism, physicians depend on the basal metabolism test. There are, however, certain symptoms that give an indication of the activity of the thyroid gland. A person with an insufficient amount of thyroxin is likely to have a dry skin and dry hair, to sweat with difficulty, to lack energy and endurance, to lack appetite, and to be overweight. There is a tendency to drowsiness and a general low condition of vitality. For the condition of hypothyroidism, physicians prescribe thyroxin (thyroid extract). Thyroxin is not destroyed by the digestive juices as most of the other hormones are, and therefore it can be administered by mouth.

Cretinism (krē'tĭn-iz'm) is an extreme hypothyroid condition found in some children. In this disease the growth of the child is slow; the bones are soft; the legs are hardly strong enough to hold the body upright; the body is heavy; the face is swelled; the hair is coarse and scanty; and the skin is thick and dry. The

child is mentally behind others of its age and may even be idiotic. If treatment is begun in time this condition can be corrected by administration of the extract of the thyroid gland.

A pronounced lack of thyroid secretion in adults results in myxedema (mĭk'se-dē'ma). In this disease there is an increase in weight, the hair becomes dry and falls out, the skin is dry, the pulse is slow, the expression of the face is heavy and rather stupid, and the mind is dull. The person is nervous and irritable and the disease, if not cured,



The thyroid gland. Its position is in front of the trachea and just below the vocal apparatus ("Adam's apple"). In cases of goiter this gland is often noticeably swelled.

may result in idiocy. This too may be cured by the administration of thyroid extract.

Hyperthyroidism. In hyperthyroidism there is in general a reversal of the symptoms of hypothyroidism. The person is alert, nervous, and restless. There is a tendency to a fast heartbeat, to a trembling of the hands, to an excess of perspiration, to increased appetite, and to loss of weight. In this condition the thyroid may be normal in size or it may be enlarged.

The symptoms of hyperthyroidism as a rule develop slowly. At first there may be only unusual activity, increased appetite, sleeplessness, and restlessness, with a general nervous condition. Mild cases of this disease may occur and disappear without treatment. This is often true of the disease in adolescents. An abundance of thyroxin in a young animal tends to cause maturity even before full growth is reached. Small tadpoles fed on thyroid gland will metamorphose into toads no bigger than flies.

Goiter. Goiter is an enlargement of the thyroid gland. The enlargement may be of the entire gland or only of one lobe.

There are two types, simple goiter and exophthalmic (ĕk'sŏf-thăl'mĭk) goiter.

Simple goiter is very common in certain areas. It is more likely to appear in girls than in boys, and there is especially likely to be an enlargement of the thyroid at about the age of adolescence. There may be no adverse symptoms unless the gland grows to a size that causes pressure and interferes with respiration and swallowing. It is unsightly, however, and it should always have the attention of a physician.

The usual cause of simple goiter is a lack of iodin. The secretion of the thyroid gland (thyroxin) is an iodin compound, and if the food does not supply enough of this element the gland enlarges. In some regions (as in parts of Switzerland, Michigan, Ohio, and Montana) simple goiter was formerly very common in both men and animals. In these areas it has been found that the soils and the foodstuffs produced on them are unusually low in iodin content, and if iodin is supplied the thyroid enlargement can be prevented. In most goitrous areas iodized salt is now used.

Exophthalmic goiter is a much more serious disease than simple goiter. It usually begins as a more or less mild hyperthyroidism. The later and more serious symptoms are gastro-intestinal disorders, extremely rapid pulse, trembling of the fingers and hands, protrusion of the eyes, flushes of heat accompanied by excessive perspiration, and increased metabolism.

Some cases of exophthalmic goiter seem to be caused by infections. In treating the condition the physician looks for diseased tonsils, teeth, sinuses, or appendix. Rest and freedom from excitement and worry are prescribed. Often the gland is treated with X ray to kill a part of the cells and reduce its activity. Sometimes a part of the gland is surgically removed. Early treatment is highly important. It has been reported that vitamin A counteracts the effects of too much thyroid secretion and that large doses of vitamin A are helpful in cases of hyperthyroidism.

THE ADRENAL OR SUPRARENAL GLANDS

The adrenal glands are found one just above each kidney. The gland sits on the kidney and fits over the top of it like a little cap. Each gland is in reality two organs in one capsule. It consists of a central part, the medulla, and of an outer or cortical part. The medulla secretes a hormone called adrenalin, or epinephrin (ĕp'ĭ-nĕf'rĭn), and the cortex a hormone called cortin.

Effects of adrenalin. When injected into the blood adrenalin increases heart activity and regulates the muscles of the blood vessels. Normally in the body it helps maintain the force of the heartbeat and normal blood pressure. At times of stress and emotion there is a marked increase in the amount of adrenalin discharged into the blood. This raises the percentage of sugar in the blood, adds to the strength of the muscles, and gives extra power of resistance against fatigue. When we need to make sudden and violent muscular effort, extra epinephrin is quickly thrown into the blood by the adrenal glands.

In medicine adrenalin is used to check hemorrhages. A solution of it applied to a wound causes the walls of the small arteries to contract and cut off the blood. It is sometimes applied as a spray or an ointment in hay fever and other congested conditions of the mucous membranes to relieve the congestion. A third use is as a heart stimulant in cases of shock and collapse, as after an operation. It is also used to relieve violent allergic attacks. Like some of the other gland extracts, adrenalin is a powerful drug and should be used only under the direction of a physician.

Function of cortin. The function of the secretion of the suprarenal cortex is not well understood. A deficiency of it seems to cause a low basal metabolism and a condition of weakness and tiredness. A rather rare and very serious disease (Addison's disease) in which the symptoms are exhaustion, weak pulse, and sometimes pain and vomiting is caused by a lack of the cortical secretion and is relieved by injections of it. Life is possible in an animal for a considerable time without adrenalin, but if cortin is

lacking death comes in a very short time. Without cortin the kidneys fail to function, there is circulatory collapse, there may be convulsions, and in general the body machine fails to run.

THE THYMUS GLAND

The thymus gland is located on the front and sides of the trachea, below the thyroid. In man it increases in size up to about the fifteenth year. Then it gradually decreases in size and in the adult disappears. In some way it is related to growth. If it is removed from young animals they become stunted, fat, and dull. Its function is not well understood, but it is believed to be connected with the growth and development of the young animal. The disappearance of the gland when growth is completed indicates that it is not important in adult life. The thymus glands of young animals are sold in meat shops under the name of "neck sweetbreads."

Among human beings it is supposed that some children suffer from enlargement of the thymus gland. Associated with the enlarged thymus there is thought to be an overgrowth of the lymphoid tissue of the tonsils, spleen, and other parts. The trouble is diagnosed with the X ray and is also treated with it.

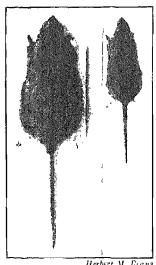
THE PITUITARY GLAND

The pituitary gland is a small gland attached to the lower side of the midbrain. It lies in a little bony pocket or hollow in the floor of the cranium above the back of the mouth. Like the adrenals, the pituitary is a compound gland. It has an anterior and a posterior lobe and each lobe secretes several different hormones. An enlargement of the pituitary and an oversecretion by the anterior lobe causes giantism and the condition known as "acromegaly," in which the bones of the face, hands, and feet are enlarged. A lack of anterior lobe secretion causes dwarfism. The giants and dwarfs of the circus owe their size to the activity or lack of activity of their pituitary glands.

Some experienced investigators believe that the pituitary is the

key gland, the master gland whose secretions control the activity of all the other endocrines.

Pituitary hormones. It is difficult to separate the many pituitary hormones and therefore a study of the functions of the pituitary gland becomes very complicated. One hormone from the anterior lobe regulates growth, as has already been indicated. from the posterior portion affects the use of food, and a lack of it leads to a great accumulation of fat. causes the tissues to retain water, persons with a low supply of it tending to be thin and dry while those having an abundance of it tend to be watery and heavy. Still another hormone, prolactin, secreted by the posterior lobe, throws the mammary glands into action. A single injection of it will not only make a male cat able to nurse



Herbert M Lians

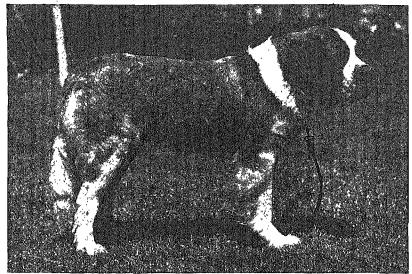
The pituitary gland was removed from both rats. The one on the left was then given injections of pituitary extract and grew in the normal manner. The other lacked the pituitary hormone and failed to grow.

kittens but it will also make him willing to nurse them. functions of the pituitary are many and as yet some of them are not well understood.

OTHER ENDOCRINES AND HORMONES

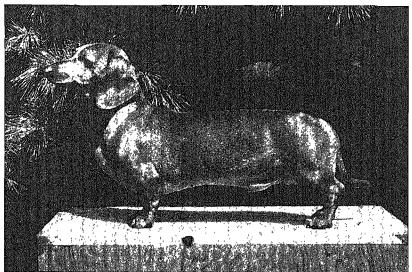
The parathyroid glands (usually four in number) are little bodies embedded in the edge of the thyroid gland. They control the concentration of calcium in the blood and when they are removed an animal goes into tetany (cramps) and convulsions.

The pineal gland is a very small structure located down between the two cerebral hemispheres, on the dorsal surface of the lower brain. It seems to work partly in opposition to the thymus. When rats were fed pineal-gland substance the offspring grew only slowly and matured when they were small in size.



Percu T. Jones

This dog has an oversecretion from the anterior lobe pituitary gland. The breed is selected for this characteristic. When old, individuals of the breed often suffer from a condition similar to what is called "acromegaly" in people.



Percu T Jones

This dog is dwarfed by lack of pituitary excretion. It has been bred for this characteristic, which gives it extremely short legs. This type of dwarfism in human beings has the long medical name of "achondroplasia."

The pancreas produces insulin, without which the body cannot use sugar. Disease of the endocrine tissue of the pancreas (Islands of Langerhans, page 503) is called diabetes. The lack of insulin is one of the common hormone deficiencies.

The sex glands secrete hormones, several of which have been isolated.

The *liver* also functions as a ductless gland. One of its hormones causes the formation of red blood cells, another stimulates heart action, a third lowers blood pressure.

There have also been found hormones in the spleen, the kidneys, and the nervous system. Several from the stomach and the intestine are known and the activities of the digestive organs are to a considerable degree controlled by them.

The study of the endocrines and hormones is called *endocrinology*. It is one of the most fascinating subjects in all biology. Among the greatest advances of modern physiology and medicine has been the progress in this field. In a medical library you will find whole volumes devoted to the subject we have just touched in this problem. It is a subject of great practical importance, for there are many splendid body machines that fail to function as they should because they are not properly regulated.

THE HUMAN BODY

In most of its features the human body is a rather primitive mammalian type, but in a few respects it is highly specialized. Man stands erect on his long hind limbs and this erect posture carries with it other modifications of the general mammalian plan. A heel helps to keep the tall, slender body from toppling over The cranium is greatly enlarged and the back part is developed until the skull as it rests on top of the spinal column is in a balanced position. The forehead is enlarged and the jaws are shortened, so that in the erect position the face and eyes are directed forward. There are present certain ligaments not found in other mammals, for strapping the intestine to the back of the abdominal cavity. In the human body the front limbs are especially noteworthy. They are freed from taking part in walking and they end in hands which are beyond comparison the most marvelous organs for manipulation found in the whole animal world.

In addition, man has a cerebrum that sets him in a class above other animals. He is a specialist in intelligence. This may not be directly related to the erect posture, but at least the upright carriage and the free hands have given the intelligence a better opportunity to manifest itself. It is the combination of the *mind* to know and the hands to do that has made man master of the earth.

In most other respects the human body is rather generalized. The digestive tract is that of an animal suited to an omnivorous diet. There is nothing individual to man in the circulatory system or the lungs. The kidneys and glandular organs are much as they are in other animals. The eyes, ears, and other sense organs are highly developed but not unsurpassed. Physically man is just an ordinary mammal with an upright posture that gives him in comparison with other mammals a height out of all proportion to his weight.

UNIT COMPREHENSION TEST

- A. What are some important characteristics of the mammals? Name the two classes of muscles. Define: dermis, epidermis. Name some modifications and outgrowths of the epidermis. Name the bones in a typical mammalian limb. What is a plantigrade animal? What living animals resemble the primitive mammals in body form?
- B. Into what parts is the alimentary canal divided? What are the accessory organs of digestion? How is food digested? What is a villus and what purpose does it serve? Describe the mammalian heart and circulatory system. Describe the respiratory system. Describe the structure of a kidney and how it functions. How is body temperature kept constant in warm-blooded animals? What adaptations to diet are found in the mammalian digestive tract?
- C. How does the wall of an artery differ from the wall of a vein? Of what is blood composed? What happens when it clots? Define: lymphocyte; leucocyte; lymph; lymphatic vessels; lymph nodes.
- D. Describe the development in the embryo of the spinal cord and brain. What are the two main divisions of the nervous system? Define the following terms: neuron; axon; nerve fiber; afferent fiber; efferent fiber; sensory fiber; motor fiber; nerve; cranial nerve; spinal nerve. Of what parts is the central nervous system made up? What are the functions of the spinal cord? Describe the development of the vertebrate brain. Locate and give the function of: the hypothalamus; thalamus; cerebellum. What part of the brain is especially well developed in man? Describe the internal structure of the cerebrum. What is the tract of fibers that connects the two sides of the cerebrum called? (Page 375.) What is the function of the cerebrum? What are the two divisions of the autonomic system? What parts of the body does the autonomic system control?
- E. What is the function of hormones? Where is the thyroid gland located? How does its hormone affect the body? What is a basal metabolism test? What are the causes and symptoms of: hypothyroidism; cretinism; myxedema; hyperthyroidism; simple goiter; exophthalmic goiter? Where are the adrenal glands located? What hormones do they secrete and what effects have these hormones? With what process is the thymus gland supposed to be connected? Where is the pituitary gland located? Mention effects of some of its hormones. Locate the parathyroid glands and give their function. What hormone is produced by the pancreas? What disease is caused by lack of this hormone? What are other ductless glands?

SUGGESTED ACTIVITIES AND APPLICATIONS

- 1. From prepared slides and from fresh material study with the microscope as many kinds of cells from the mammalian body as you can. The drawings on page 108 will be of assistance to you.
- 2. Voluntary muscles may be attached to the bones either directly or by tendons that extend to parts at a distance. Feel your forearm while you close your hand. Move each of the fingers independently. Where are the muscles that move the fingers?

Where are the muscles that move the foot? that bend the leg at the knee?

3. Remove the mineral material from the leg bone of a chicken or turkey by soaking it in 2 per cent hydrochloric acid. (See workbook.) After removal of the mineral matter, of what is the bone composed? What purpose in the bone does the mineral matter serve?

The animal material may be removed from a bone by burning it in a hot fire. After a solid piece of bone has been burned, try breaking it. What purpose does the animal matter serve?

4. Feel the pulse in your wrist. Count it. Have someone squeeze your upper arm. What happens to your pulse?

Count your pulse when sitting, standing, and lying down. Exercise rather violently and count your pulse again. Record in your notebook the different pulse rates.

- 5. Run your finger down the forearm along the vein. Do you see small knots in the vein? These are little valves inside the vein. They are pockets on the wall formed much like the outside pockets on a coat. When the blood moves backward, they swing out from the wall and block the opening of the vein.
- 6. In a small electrically heated incubator place some fertile hen's eggs. (The eggs may be kept warm with an electric light bulb placed in an insulated box.) Keep the incubator at about 103°. Turn the eggs over twice each day. In winter see that the eggs are not chilled between the time they are laid and the time of placing them in the incubator.

Take an egg from the incubator each day and break it gently in a saucer. Study the developing embryo. Look for the primitive streak which develops into the nervous system and for the body somites (page 491).

With an incubator that has a regulator on it the temperature can easily be kept constant until the eggs hatch. With a home-made one, it may be best to terminate the experiment after a few days.

Reference

NEWELL, MARTIN H. The Human Body. Henry Holt & Co., Inc., New York.



unit 12 THE PLANT PLAN

The plant way of life is very different from the animal way. The tissues and organs of the plant show corresponding differences.

> "We are so familiar with the plants of the modern world grass or oak tree, rosebush or bindweed - that we forget what evolutionary triumphs they embody, what difficulties surmounted, what adjustments perfected." H. G. WELLS

THE GREEN PLANT

QUESTIONS FOR CLASS DISCUSSION

If one of the larger land animals were confined to a single spot, what pressing difficulties would it find itself in?

How does a plant overcome these difficulties?

A PLANT has no nerves or muscles or jointed skeleton. It has no mouth, no digestive tract, no lungs, no heart, no kidneys for the excretion of protein wastes. It does not roam about in search of food, but stands and makes it. It is a stationary living factory, powered by the sun and drawing its raw materials from earth and air. Naturally an organism that lives as a plant does must differ very markedly in both its structure and the functions of its parts from an animal that subsists on prepared food.

The differences between the plant and animal types trace back to the greater chemical building power of the plant. By photosynthesis a plant can manufacture sugar and store the energy of the sunshine in it. Then by secondary chemical processes it can transform the sugar into other substances. By the addition of minerals from the soil it can build proteins. The supreme chemist of the world is the green plant. No animal, not even man with all his science, can start with simple materials of the soil and air and build living protoplasm as the humblest roadside weed does.

In this unit we shall pass over the simple plants and those that lack chlorophyll and shall study as the plant type the larger green plants of the land. In plants as in animals, there can be large size only where it is accompanied by tissue differentiation and special organs for different kinds of work. These we find in the ferns and seed plants. The principal vegetative parts of such a plant are the roots, stem, and leaves. These organs we shall study, together with the tissues of which they are made and

the processes that go on in them. Since ferns are simpler in structure than the seed plants, we shall in our first study of plant tissues use the fern stem. Then we shall study the structure of the different vegetative parts of the flowering plants and the function of each part.

Problems in Unit 12

- 1 What are the functions of the different plant organs, and how is the plant body controlled?
- 2 What are some of the principal plant tissues?
- 3 What tissue arrangements do we find in the stems of flowering plants?
- 4 What adaptations for food making do we find in leaves?
- 5 How do roots carry on their work?
- 6 What makes a soil fertile, and how can soils be improved?

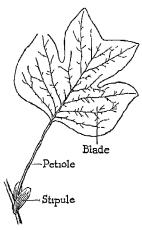
PROBLEM ONE

What Are the Functions of the Different Plant Organs, and How Is the Plant Body Controlled?

Each part of the plant has its own work to do. All the parts taken together make up a complete organism. What is the function or functions of each part? How without a controlling nervous system are all the parts made to work together for the good of the plant as a whole?

Function of the leaf. The function of the leaf is to make food. In it photosynthesis is carried on and sugar is formed. We speak of a green plant as being independent and manufacturing its own food, but it is only the leaves (or other green tissue) that can make food from simple inorganic materials. The roots of a plant and the colorless tissues within the stem are as dependent on the leaves as are animals.

A leaf may be simple or it may be compound (page 895). It may have a petiole (pět'ĭ-ōl), or leafstalk, or have a base that clasps the stem. Stipules (stĭp'ūls) may be present or absent. Leaves differ endlessly in size and shape, but they are alike in



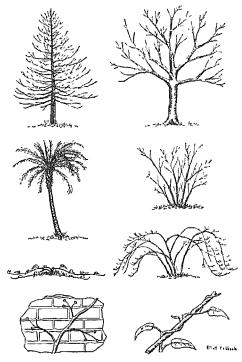
Parts of a simple leaf. In a compound leaf the blade is divided into leaflets.

that they expose a great area of green tissue to the light. It is estimated that the leaves on a large spreading oak tree would cover an area of half an acre.

Functions of stem. The first function of the stem is to hold the leaves up to the light. A plant makes its food by photosynthesis and to carry on this work a large plant has a multitude of leaves. The stem bears the leaves and displays them to the light. A tree builds a great wooden stem that carries thousands of leaves and is strong enough to support them in the wind. Vines are not strong enough to stand

alone, but many of them get their leaves to the light by clinging to supports. Others, like the cucumber and pumpkin, trail and spread out a wide expanse of green foliage to the sun. It is the business of a stem to bear leaves and to expose them to the light. Examine the stem of almost any plant and you will find that it has a way of getting this work done.

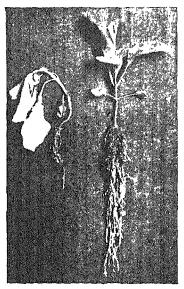
The second function of the stem is to conduct food and water through the plant. When leaves are lifted high above the roots the stem must certainly provide some way of getting water up to



Different types of stems. Whatever the structure or habit of growth of a stem, it exposes leaves to the light.

them and of distributing through the plant the food that the leaves make. The stem therefore conducts great quantities of water and the minerals that are dissolved in the water up to the leaves, and it carries the food from the leaves down to the roots or out into the flowers, fruits, or young shoots. It serves as a middleman between the roots and the leaves.

Functions of roots. One function of roots is to anchor the plant and hold the stem upright. A hard wind exerts a tremendous force against a tree and if the roots did not hold fast the tree would be at once overturned. If you have tried to pull a plantain or a dandelion out of a lawn you will understand how firmly even a small plant is anchored in the soil. Without roots to act as holdfasts there could be no large land plants.



A cabbage plant carelessly pulled from the seed bed and one carefully removed to preserve the roots. If, in transplanting, the root system is too badly injured, the plant is likely to die from lack of water before new roots can be grown.

A second function of roots is to secure water and mineral food materials from the soil. A plant constantly gives off water through its leaves and this water must be replaced. It requires for its growth and nutrition mineral salts. The roots of a plant spread far out in the soil and gather the water and minerals that the plant requires. A young plant must develop roots before the top parts can be exposed to the air and light. The root system of a young seedling is often more extensive than the above-ground parts.

A third function of roots is that of food storage. This is particularly true of fleshy roots like the carrot, turnip, parsnip, radish, dahlia, and sweet potato. Many

trees and other seed plants that live on year after year have food stored in the roots during the winter months. This food is used the next year in building leaves and new stems or twigs.

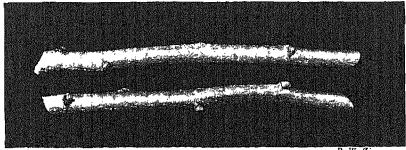
Control of the plant body. To a considerable degree a plant is controlled by outside stimuli. Leaves are influenced by light. Gravity causes the stem of a seedling to turn up and the root to turn down. Roots grow toward water or fertilizer in the soil. The flowering of many plants is determined by the length of day. A plant in a hot exposed situation will develop a thick epidermis on its leaves. Notice plants of the same kind in different situations and you will see that outside influences have a great effect on them. Climatic and soil conditions have a great effect on the growth and characteristics of plants, as every plant grower knows.

The plant body is controlled by internal influences also. There is something inside the plant that conditions it, that makes it act as it does. There is something within that determines the form of the plant, the size to which it will grow, the way it will respond to outside stimuli. This internal regulation of the plant seems to be carried out by hormones — chemical substances formed in various parts of the plant. For example, there is something produced in the tip of a climbing bean vine that keeps side branches from starting on the vine. But if the tip is pinched off, side branches will start. There is something produced in the roots of a willow that keeps new roots from starting out up above. If a willow branch is cut off from the influence of the roots below and set in water, new roots will quickly form at its base.

An instructive experiment. Do you know the shrub that is called althea or rose of Sharon? It is a member of the hibiscus group and has hollyhock-like rose-colored flowers. If you can obtain some small branches from an althea plant, you can perform an interesting experiment with them.

Set some cuttings of althea in a vessel with just a little water in the bottom of the vessel. Then cover the cuttings with a bell jar to keep them in a moist atmosphere. The buds on the cuttings will start into growth.

Now repeat the experiment with cuttings from which the buds have been removed. New buds start into growth all over these cuttings. In the first set of cuttings the growing buds in some



P. W. Zimmerman

Cuttings of althea, showing the buds.



P. W. Zimmermar

From the cutting on the left all the buds but one were removed. This started to grow and prevented other buds from developing.

All the buds were removed from the other cuttings and numerous new buds were formed and started their growth. In time, some of these will gain the upper hand and restrain further bud development.

way prevented new buds from being formed. In the second set the restraining influence is not present and a multitude of buds burst out. Just what it is that the growing buds produce that prevents other buds from forming we do not know.

As yet we know little of plant hormones, except that they exist. Substances have been extracted from the buds of plants that influence the growth of other parts, but only one of these substances (the gas ethylene) has been identified. A curious fact is that certain chemical compounds not found in plants at all seem to give practically the same effects as some of the hormones that the plants produce. Some of these substances are now used extensively to secure a quicker rooting of cuttings. Application of some of them to the pistils of flowers causes the fruits to develop without pollination and in this way seedless watermelons, tomatoes, and other fruits have been produced.

Experiments with pieces of plant tissue in cultures seem to prove that the stem of the tomato makes vitamin B (thiamin) and that the root cells do not make this substance but must have it in order to grow.

The plant as a whole. The animal body is made up of many organs and parts, each with its own definite function. All these parts are adjusted and controlled to make one greater whole. The plant is organized in the same way. The roots from the soil draw water and minerals that are necessary for plant life. The leaves build these raw materials into food. The stem exposes a great leaf area to the light. A system of vessels makes possible the flow of water and food through all the plant. By responses to outside conditions and by hormones within, the growth and the functioning of the different parts are controlled. Watch a tree through a growing season or a smaller plant through its life cycle. The plant shows by its constant adjustments that it is as truly an organism as is an animal.

The members of some Hindu cults eat only vegetable foods because they think it wrong to take life. We gather flowers and cut down plants without the same feeling of destroying something alive that we have when we kill animals. These beliefs and feelings result from forgetting the plants in our thinking about living things and looking on the animal world as the whole life realm. In reality the green plants occupy the fundamental position in the biological scheme. Think of them as living beings that differ markedly from animals because they are adapted to a wholly different food-getting plan.

PROBLEM TWO

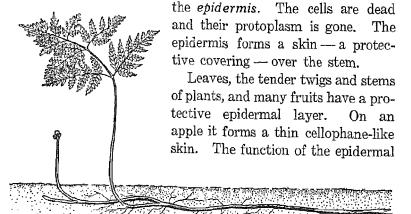
What Are Some of the Principal Plant Tissues?

Over a large part of our country there grows a kind of fern called the brake, or "bracken" fern. Its botanical name is *Pteris*. Most fern stems are very short and the leaves grow from them in clusters. The Pteris stem may be several feet long. It grows horizontally underground and the leaves of the fern grow up from it at points some distance apart.

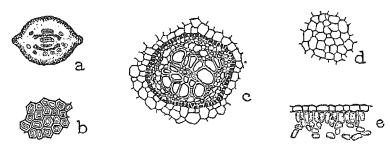
If we dig up and examine a Pteris stem we find that it is a hard, dark-colored, somewhat flattened rod perhaps a half inch in diameter. Occasionally it branches. Roots are attached to it and at intervals leaves grow up. A young plant sends up from seven to twelve leaves the first year. After that the stem pushes along rather slowly through the soil and sends up only one leaf each year.

Tissues of Pteris stem. A cross section of the Pteris stem when placed under the microscope shows a great differentiation of the cells. Four important kinds of tissue are:

(1) Epidermis. Under the microscope, you will find at the outer border of the section a single layer of cells. This layer is



Pteris, the bracken fern. Only the leaves appear above the ground.



Tissues and tissue arrangements in Pteris stem. a is a cross section of the stem. The darkened outside layer and the two elongated dark bands are sclerenchyma. The circular and oval bodies are bundles. b shows sclerenchyma cells with very thick walls and only small open spaces in the interior of the cell. c is a bundle with the endodermis about it and the large open water vessels within. d is a group of parenchyma cells, and e shows the epidermis on the Pteris leaf.

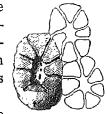
covering is to protect the tissues within from drying and from the bacteria and fungi of decay.

(2) Sclerenchyma. Next, just inside the epidermis of the Pteris stem, comes a considerable layer in which the cell walls are thickened. This hard layer, like the outer layer of a cornstalk, supports the stem and protects the tissues within. It is sclerenchyma (skle-rěng'kĭ-ma; Greek skleros, hard).

The sclerenchyma is dead — the protoplasm of the cells has built up the thick cell walls and then died. In addition to the outer layer of sclerenchyma you will find two flattened strands of it in the interior of the stem. Cut into the stem with a knife and you will quickly recognize these strands by their hardness. They

run lengthwise in the stem and stiffen it. The fern has become so large that it needs hard tissue for support. The shells of nuts are composed of very thick-walled sclerenchyma. In plants sclerenchyma is used for protection as well as for support.

(3) Vascular tissues. Scattered through the stem are round or oval groups of cells. These are the fibrovascular bundles. Their function



Sclerenchyma cells from the shell of a pecan.

is to conduct water from the roots through the stem up to the leaves and to bring food from the leaves to the stem and the roots. The large open cells in the bundle are the water vessels. Around each bundle is a layer of cells that encloses it and sets it off from the other tissue. This is the *endodermis*. The large open water vessels are called *tracheae* (singular, *trachea*).

Branches from the fibrovascular bundles go out into the roots and up into the leaves. In a tiny alga each cell makes its own food and in the smaller mosses food and water diffuse along from one cell to another until they reach all parts of the plant, but a fern is so large that a special conducting system is necessary. The leaf is up in the air away from a water supply and the stem and roots are down in the earth away from any cells that have a chance to make food. There must be vessels to carry the water up and the food down, and these are in the bundles. In the fern we have come to a plant large enough to require different tissues to carry on its life.

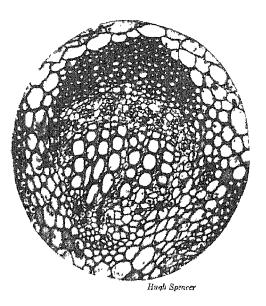
(4) Parenchyma. The fundamental or background tissue that is found in the Pteris stem — the part that is neither sclerenchyma nor bundles — is parenchyma. It is made up of large, thinwalled living cells in which starch is stored. Parenchyma is the kind of tissue we find in the pith of a stem or making up the main body of a potato, radish, or beet. It is undifferentiated plant tissue formed by young plant cells that grow larger but keep their thin walls and do not change into any special kind of cell. We might define it as the plant tissue that has not been changed into anything else. The ground tissue of a stem is parenchyma. Young tissue is parenchyma. Undifferentiated tissue is parenchyma. "Everything is parenchyma that is not something else."

Structure of a bundle. Now let us turn our attention to the tissues within a bundle. For this study we shall use a bundle from the stem of a dicotyledonous plant. On one side of the bundle is *xylem* (zī'lěm). This consists of thick-walled wood fibers and of long open vessels for water conduction. On the other side of the bundle is the *phloem* (flō'ĕm). This contains food vessels, and in many plants a mass of fine, dead, thick-walled

TISSUES OF PLANTS

A bundle from a sunflower stem photographed through a microscope. The dark tissue at the top (outside) of the bundle is the phloem; the layer of small cells below the phloem is the cambium; and the large open cells in the center are water vessels. Near the bottom is a group of rather small thick-walled wood fibers. The large cells about the bundle are parenchyma.

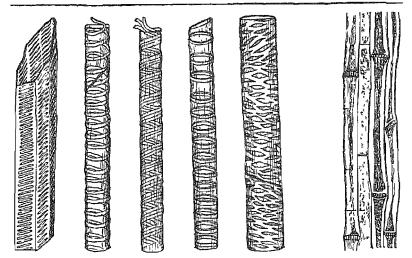
fibers called *bast fibers* — or all together, the *bast*. As you will see if you examine bundles



with the microscope, many cells within a bundle may remain unchanged. They do not become xylem or phloem but continue to be parenchyma. Wood parenchyma is found on the xylem side and phloem parenchyma on the phloem side.

Between the xylem and the phloem is the cambium. This is a layer of thin-walled growing cells. These cells multiply and on one side the new cells turn into xylem and on the other into phloem. Always, however, in the center of the bundle a layer a few cells thick (the cambium) remains in an undifferentiated growing condition and by the multiplication of the cells of this layer the bundle grows. We call this an "open" bundle because phloem and xylem are separated by cambium and are so arranged that the bundle is open for further growth.

The water vessels. The water vessels in ferns and flowering plants are formed from large, long cells that are arranged end to end. The side walls of these cells are lined with wood and the end walls between the cells are absorbed. The living contents of the cells then die and the vessels thus formed are left standing as long tubes in the stem. In vines these are often especially large. You can light and smoke a piece of dead grapevine or of dry willow root, drawing the smoke through the empty vessels. By fitting a short section of a branch from a dicot tree (not a conifer) into the hose of a bicycle pump and placing the end of the cut



On the left are tracheae (water vessels) of different types. All of them are long open tubes through which water flows upward to the leaves. Sieve tubes (food vessels) and the long parenchyma cells that lie among them are shown on the right. (After Bastin.)

branch under water, you can force air through the wood and see the bubbles emerge from the wood "pores." In a large tree the heartwood has lost connection with the leaves and the ascent of water is through the outer wood layers (sapwood).

When flowers are cut from a plant at a time when transpiration is active, air is likely to be pulled into the bottom ends of the little water vessels. Then when the flowers are put into water they wilt because the vessels are blocked by the air. The remedy is to put the stems of the flowers in water and then cut off the lower ends under water. Or if the stems are held for just a few minutes in quite warm water the air will be driven back out; then they may be quickly transferred to cold water, which will be drawn up into the vessels as the stems cool. After cut flowers have stood for a few days a gummy growth of bacteria in the dead tissues at the cut ends may close the vessels. This block can be removed by cutting off the lower ends of the stems.

The food vessels. The food vessels are in the phloem and they are much smaller and thinner-walled than the water vessels. The chief ones are the *sieve tubes* through which the protein foods are conducted. The sieve tubes get their name from the fact that their end walls are perforated with holes like the lid of a salt shaker. Through these openings the food materials pass from cell to cell. Sieve tubes are short-lived and new ones are continually being formed by the division of long thin-walled cells that lie in the phloem alongside them. Sugars are moved through these long cells by passage from cell to cell. In a tree the food vessels lie in the inner part of the bark. Farmers kill trees by girdling them — cutting away a ring of bark about them. They cut the food vessels so that food cannot go down to the roots and then the roots die.

Food, however, does not always travel downward in a plant. In the spring food that has been stored in the roots moves upward

in many plants and is used in building the new twigs and leaves. When a new shoot appears on the side of a branch, food travels into it. The food goes from the place where it is most abundant to where it is least abundant. In summer this usually causes it to move from the leaves to the roots or to a growing part.

Characteristics of plant cells. One characteristic of many plant cells is that they thicken their walls by depositing various materials in layers on the inside of them. In this way sclerenchyma, wood fibers, cork cells, the strong stringy fibers that you find on the inside of the bark of a tree are formed. In general, the hard supporting tissues of plants are formed by cells that thicken their walls and often die after this has been done.

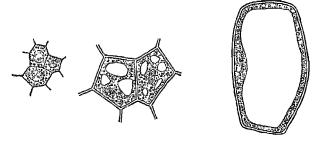


A plant cell, showing the large amount of space occupied by the cell sap. (After Bastin.)

A second characteristic of mature plant cells is that they usually contain large amounts of water. In some of them the living matter forms only a thin layer lining the cell wall (page 530). In others, in addition to the lining layer there are strands of cytoplasm suspended in the cell space. As has already been explained, the water within the cell and the dissolved

materials in it is called "cell sap." The space it occupies is spoken of as a *vacuole*.

Growth in plants. In respect to plants we use the word "growth" in two meanings. There is growth in the tips of stems and roots and in the cambium where new protoplasm is being



Plant cells, showing how enlargement takes place by the taking of water into the cell. (After Prantl.)

built and cells are dividing. We speak of these as growing regions of the plant. In them there is growth by the building of new cells and new living material.

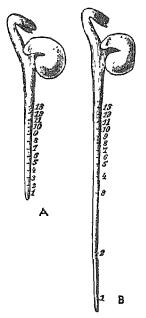
There is another kind of growth through the enlargement of cells. In the spring the new twigs, leaves, and flowers are already formed and lying in the buds. They suddenly appear because they are enlarged and forced out by the pumping of water into their cells. By this means the volume of a cell may be multiplied a thousandfold. As the cell enlarges the walls stretch and are kept intact by the addition of new material to them. Mark off with India ink spaces of ½ inch for the first few inches from the tip of a morning-glory or other quick-growing vine. Then watch the increase in length of each division. You will find that the greatest lengthening is back from the tip where the cells are absorbing water and increasing in size.

Tissue development in plants. In plants as in animals, the various tissues are developed by differentiation of the cells. If you could examine a section cut through the tip of a growing fern stem, you would find that at the tip all the cells are young parenchyma. These cells divide and by their increase in

number they build the front end of the stem forward. Farther back in the stem as it grows older you would see some of the cells thickening their walls and becoming sclerenchyma, and groups of others lengthening out into vessels to make bundles. Each tissue connects with the older tissue of its own kind; and as a background, filling in between the other tissues, the parenchyma cells grow larger but in character remain unchanged (page 132).

If we wish to find young tissues and to see tissue differentiation in animals we must study the animal in the embryo stages. In a plant, not only in the embryo but in the growing stem and root tips, the cells are young and back of these young cells tissue differentiation is going on. A giant sequoia that began life 4000 years ago still carries youth in the tips of its twigs.

The development of vessels in plants may be compared to the development of the circulatory system in animals. The introduction of hard and strong support-



A. A young root of a pea marked off in millimeters.

B. The same root 24 hours later, showing elongation almost entirely in the terminal 5 millimeters. This growth is the result of filling with water the cells already formed.

(After Frank.)

ing plant tissues may be compared to the introduction of the spinal column and other bones of the vertebrate skeleton. A land plant and a land animal have certain common problems and each has developed tissues that enable it to meet these problems in its own way.

PROBLEM THREE

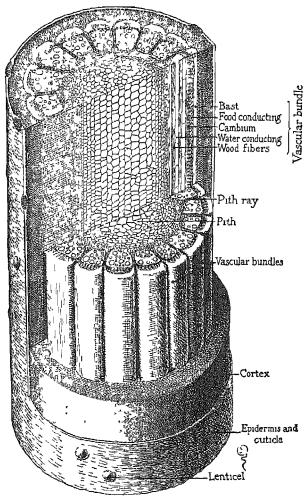
What Tissue Arrangements Do We Find in the Stems of Flowering Plants?

In all the flowering plants we find the kinds of tissues we have studied, but in the stems of these plants there is great variation in tissue arrangement and tissue development. We shall now study the characteristic differences in several types of angiosperm stems.

Characteristics of dicot and monocot stems. In a dicot stem the bundles are set in a circle. In the center, inside the bundle circle, is a region of soft parenchyma cells called the *pith*. Outside the bundles is another region called the *cortex*. Depending on the abundance of the bundles and the amounts of wood they develop, a stem is *woody* or *herbaceous*.

In the monocots the bundles are scattered all through the stem, as you can see in the pith of a cornstalk. There is no distinct cortex as there is in dicots, but in many of the monocots the outer tissue is a hard sclerenchyma layer. The stem is stiffened and strengthened by this hard outer layer and the bundles that run like elastic wires through it also add greatly to its power to stand before the wind. Most monocot stems are unbranched.

Structure of woody dicot stem. Suppose we examine a young woody dicot stem, such as we find in the small branch of a tree. In the center of the stem is the pith, around which the bundles are set so close together that they form practically a continuous ring. Between the bundles, however, there are narrow strands of parenchyma cells that extend out from the pith to the cortex. These strands of cells are called *medullary* (měďu-lěr'í) rays. The word "medulla" means the middle, and these are rays that radiate out from the central portion, or pith. In a cross section of wood you can easily see the medullary rays. In some trees they may be a half inch or even an inch in height. They are ribbon-like bands of soft tissue set on edge in the wood. In



Stem of a moonseed vine, a herbaceous dicot.

quartered oak we see the sides of the rays as spots and bands in the wood. The gymnosperms have a different type of water vessel from the angiosperms, but in general the stem of a gymnosperm (pine, cedar, fir) is in structure much like a woody dicot stem. Structure of bark. The bark of a tree is made up of the cortex and the phloem. It separates from the wood at the cambium layer. Bark is formed by the outer cells of the cortex thickening their walls with cork and after a time dying. This gives an outer waterproof covering that protects the living cells within from drying.

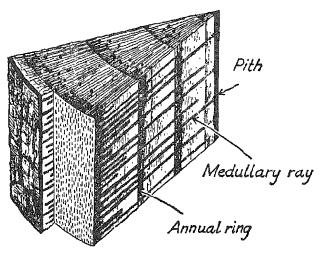


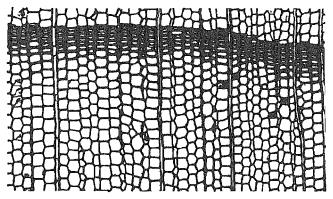
Diagram of the stem of a 4-year-old pine. (After Strasburger.)

As a tree increases in diameter the cortex grows by the multiplication of cells within it and the outer corky layer is thickened year by year from within. In some trees this dead outer part of the bark scales off promptly and the bark is relatively smooth. In other trees the outer part hangs on tenaciously and deep cracks are split in it by the increase in diameter of the trunk. On the inner side of the bark you can find the stringy fibers of the bast. The other cells of the phloem are so thin-walled and delicate that they are not noticeable in a piece of bark. In a living tree the inner layer of the phloem is alive but the older outer part dies.

In the spring when growth is active the cells of the cambium layer are young and delicate and at this season the bark can easily be broken loose from the wood and stripped off. When you make

a willow, hickory, or maple whistle in the spring you separate the bark from the wood along the cambium layer.

Growth of woody stem. A tree grows by the multiplication of the cells of the cambium layer. On the inner side the new cells turn into wood. Each year (or growing period) a new layer of wood cells is built on the outside of the wood of the year before.



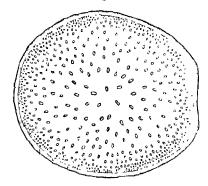
Annual ring in cypress wood. As growth slows up in the autumn the cells are smaller and thicker-walled.

The wood fibers and vessels that are formed in the spring are relatively large; as the season advances and growth slows up they become smaller. This causes the *annual rings* that we see in the stump of a tree or the end of a log or piece of timber. By counting the rings the age of the tree can be determined, and an examination of them shows how rapidly the tree grew and which years were good and which bad for growth. On the outer side of the cambium phloem is formed, but in a tree there is much less of this than of the wood. The cell walls of the phloem are very thin and the old phloem is crushed on the inside of the bark as the new phloem grows.

Some of the great sequoias in California are 4000 years old and in their rings is a record of the climate during their lives. Timbers that were cut and placed in houses 1200 or 1500 years ago by the cliff-dweller Indians can be quite accurately dated by the cycles and succession of thick and thin rings that are found in them. A board is a slab of xylem cut from a tree and the patterns in it are the result of the way the saw went through the rings and medullary rays. There are many points of interest in trees and woods to one who understands the structure of a woody stem.

Herbaceous stems. In the herbaceous stem the bundles are much less prominent. Throughout the temperate regions practically all these stems live but a single year. In consequence there is in them no adding of annual rings of wood or continuous growth of a thick bark from within. Often much of the strength of the stem comes from a rind — the outer coat of hardened tissue (sclerenchyma) — and the chief function of the bundles is to conduct the food and water. In such stems the pith is relatively large. Sometimes it dies and breaks down, leaving the stalk hollow.

The dahlia, zinnia, chrysanthemum, sunflower, and annual weeds are examples of plants with herbaceous stems. Since these



Stem of a cornstalk, showing the scattered arrangement of the bundles typical of the monocot stem. (After Strasburger.)

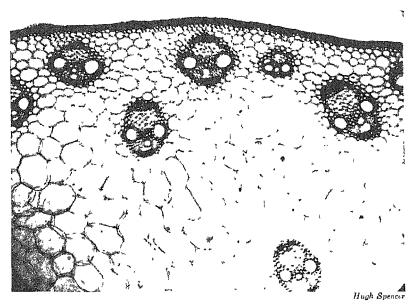
stems lack the strength of a woody stem they cannot grow to the size attained by trees. A dahlia the size of a large tree would not support even its own weight.

The monocot bundle is different from that of the dicot. It has no cambium. The phloem is in the center and is enclosed by the xylem. There is no growth in the monocot bundle, no laying down of "secondary" wood

and phloem after the bundle is formed. A monocot bundle is called a "closed" bundle in contrast to the "open" bundle of the dicots. It is said to be closed because there is no cambium and the xylem usually surrounds the phloem, enclosing it so that the bundle is closed to further growth.

Cattails, rushes, grasses, lilies, and cannas are examples of

STEM STRUCTURE



Partial section of a cornstalk photographed through a microscope. The monocot bundles have no cambium.

monocots. The stems of some of them (as asparagus) come up out of the ground almost as thick as they ever become, and growth in them consists chiefly of adding tissue at the top. What growth in diameter there is comes by multiplication and enlargement of the parenchyma cells and by the formation of more bundles in this new tissue.

One of the great monocot families is the grasses. In these the stem is hollow and jointed, and in some members of the family it represents a wonderful combination of lightness, flexibility, and strength. A stalk of wheat has a height 400 times its diameter; yet it can carry a head much heavier than itself and can straighten up after it has been bent far over by the wind. A large species of bamboo, which is just a giant grass, may send up a stem 60 feet into the air and for its weight the strength of this stem is very great. In the palms, which are the only tree family of monocots, the bundles in some species are set so close together that the tissue is as hard as oak. Some of the slender species have trunks

so elastic that in a tropical hurricane trees 50 feet high can bend over without breaking, until the tops touch the ground.

The strength of many of these stems is explained in large part by the strength and elasticity of their bundles. A fine cloth is woven from the pineapple fibers. These fibers are the bundles from the leaves and a single fiber is far stronger than a steel wire of the same thickness. Rope is made from the fibers of a bananalike plant that is called Manila hemp and these fibers are the bundles combed from the long petioles (stems) of the leaves. You can test for yourself the strength of one of these bundles. Binder twine is made from the bundles of sisal (sī'sal), a monocot that grows in Yucatán and is much like the century plant.

The fibers obtained from dicots are not whole bundles but only the bast. Linen is made from the bast of the flax plant. Jute, which is used in the manufacture of twine, burlap, and carpets, is the bast of the hemp plant.

We have in this and the preceding problem studied the tissues found in plant stems. These same tissues are found in the roots and leaves.

PROBLEM FOUR

What Adaptations for Food Making Do We Find in Leaves?

A leaf is an organ fitted for a perfectly definite work. In it the green cells are spread out in a thin sheet so that the light can reach them. Running in among these cells are vessels that bring water and minerals into the leaf and carry food away. The function of the leaf is to make food. It is a food factory and the energy that operates the machinery of the factory is the light of the sun.

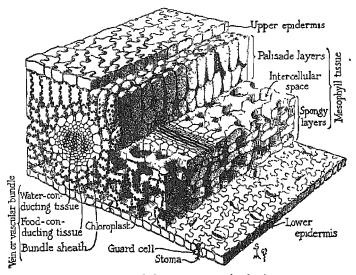


Diagram of the structure of a leaf.

Structure of a leaf. Under a microscope a cross section of a typical leaf shows a colorless layer of flat cells on the upper and lower surfaces. This is the epidermis, which encloses the green working cells. It has already been described (page 524). Beneath the upper epidermis is the palisade layer, a compact layer of elongated green cells standing on end. Then beneath these we find the spongy parenchyma made up of soft green tissues

with the cells loosely built together and air spaces among them. At places you will see where the veins have been cut across.

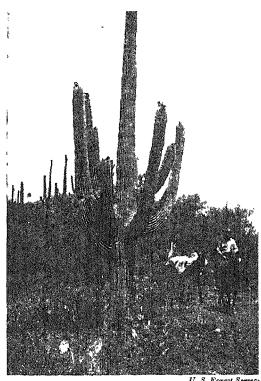
The veins in the leaf are continuations of the bundles of the stem and they serve two purposes. They support the leaf mechanically and the vessels in them bring water and minerals to the green cells and take away the food that these cells manufacture. At the outer ends the veins in a dicot leaf may contain only a single water vessel and a single food vessel, but these small veins are joined into larger ones in the ribs and petioles of the leaves. In the leaf the vessels lie in contact with the green cells and the water and food pass between the vessels and cells by diffusion through the walls.

The epidermal cells are alive, but they lack chlorophyll. Usually the outer wall is thickened with a waxy substance called *cutin* (kū'tǐn). You can strip the delicate papery epidermal layer from a leaf. Its function is to waterproof the leaf and keep it from drying out. Tender shoots are covered with an epidermis of the same type. The stomata, or minute openings in the epidermis, provide for an exchange of gases between the interior of the leaf and the outside atmosphere (page 196). Each stoma lies between two crescent-shaped *guard cells* that by coming closer together or springing apart can change the size of the opening.

Transpiration. A leaf loses water through the stomata to the air. The evaporation of water from the leaf is called transpiration. On a hot day the transpiration is beneficial because of its cooling effect. It may lower the leaf temperature as much as 18°F. Transpiration is also unavoidable. If openings are provided that allow the exchange of oxygen and carbon dioxide between the leaf cells and the atmosphere, the loss of water from the leaves cannot be prevented. The need of leaves for water to make good their transpiration loss on a hot dry day is great. A fair-sized apple tree on an average summer day may lose 30 gallons of water and in the hot season a large date tree in the Sahara Desert may in a day transpire 200 gallons. This water must come up through the vessels of the stem and the upward current may easily be at the rate of 6 or 8 feet an hour.

ADAPTATIONS OF LEAVES

Chlorophyll. The chloroplasts of the interior cells of the leaf contain the green pigment that we call chlorophyll. This amazing compound by the process of photosynthesis makes sugar out of water and carbon dioxide. It catches the energy of the sunlight and stores it in sugar. Chemically chlorophyll is similar to the hemoglobin of our blood, but in the molecule it has magnesium instead of iron. Chlorophyll appears in the chloroplasts when they are exposed to light. Grass under a board is a whitish vellow. but if the board is removed the grass will soon turn



Desert plants. As an adaptation to their growing conditions they have small, tough leaves or even no leaves.

dark green. If you will grow a pot of wheat seedlings in the dark and then set them in the sunshine you will see the green appearing in perhaps half an hour.

Adaptation of leaf for its work. The function of the leaf is to manufacture food. The structure of the leaf adapts it admirably for this work. The broad, thin blade permits the display of a wide area of green tissue to the light. The spongy grouping of the cells allows gases to circulate among them. transparent epidermis allows the light to reach the green cells and protects them against too great drying. The stomata provide for the necessary exchange of gases with the atmosphere. The vascular system brings to the working cells water and minerals and carries away the manufactured food. Leaves are marvelously effective organs for displaying chlorophyll to the light.



Plants in a moist woodland. The plants that grow under such conditions have leaves that are broad and thin.

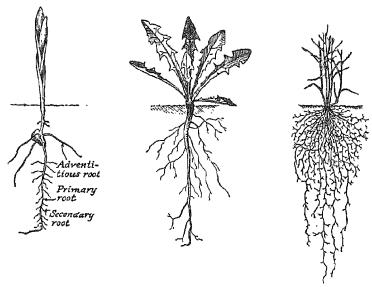
Adaptations of leaves to external conditions. In a dry region the plants have small, tough leaves or even no leaves. In shady places and where there is plenty of water in the soil they have broad, thin leaves and many of them. The size of the leaves and the number of them on a plant must be adjusted to the amount of water that the roots can absorb and send up to them. In regions of intermittent rainfall practically all plants are at times limited in their growth by lack of sufficient water and are helped by irrigation or watering.

Leaves are of many shapes and sizes, but the function of all of them is the same. Life requires energy. The primary source of the energy by which a green plant lives is the sun. The leaf is an organ for catching solar energy and fixing it in molecules of food.

PROBLEM FIVE

How Do Roots Carry on Their Work?

When you look at a tree or an herb you usually see about half of it. The other half is down in the ground, growing, branching, and pushing out through the soil as the stem grows and branches and pushes up into the air above. Our subject in this problem is the great underground portion of the plant.



Corn seedling (left), showing primary, secondary, and adventitious roots. The dandelion and grass are examples of tap-rooted and fibrous-rooted plants.

Types of root systems. Germinate a grain of corn. The first root of the young plant is the *primary root*. As the plant grows, *secondary roots* branch out from the primary one. *Root hairs* appear as a fuzz back of the growing tips.

Sometimes the primary root continues its growth as the main root, giving off only small side branches. This is a *taproot*. A dandelion, clover, alfalfa, or carrot plant has this type of root. Among trees the pine and walnut, hickory and pecan, have tap-

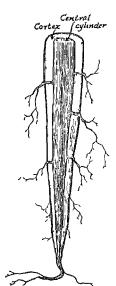
roots. A plant with a taproot is hard to transplant, and in soil that heaves with the frost the taproot of a small plant is likely to be broken by the freezing of winter.

In other plants the primary root of the seedling breaks up into many fine branches, or a multitude of new roots (adventitious roots) come out from the bottom of the stem as the plant grows. These are *fibrous-rooted* plants. The bean, corn, cabbage, squash, and grasses are familiar plants of this kind.

In general, taproots go deep into the soil rather than sidewise and plants with roots of this type (e.g., radish, carrot, beet) can be grown close together.

Structure of roots. Cut a carrot crosswise (a dandelion root will do). In the center is a core that contains woody tissue. This is the *central cylinder*. Around the central cylinder is the *cortex*. Covering the carrot is the epidermis.

Now split the carrot lengthwise. Perhaps you can find places



Longitudinal section of carrot, showing structure of a root.

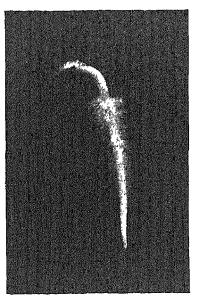
where branches from the central cylinder run out through the cortex. These branches go off into the secondary roots. The central cylinder contains the food and water vessels and these are connected with all the small roots of the plant.

A cross section of a small growing root placed under a microscope will reveal its structure in detail. It is composed of cells, as you already know, and these are not all alike. The cells on the surface are flattened—shaped like bricks. These make the epidermis, or outer covering layer. Occasional cells of the epidermis grow outward and become root hairs. These push in among the soil particles and absorb water and minerals. On a growing rootlet you can with the unaided eye see the root hairs like a zone of delicate fuzz just back of the tip. The root hairs are living cells. Each one has a nucleus

and a layer of cytoplasm lining the cell wall. Its interior is filled with cell sap.

The central cylinder of the root is composed of xylem and of phloem. The xylem contains thick-walled wood fibers that strengthen the root, and vessels that carry the water upward to the stem and leaves. The phloem contains vessels that bring food down to the cells of the root. The water goes up in the vessels of the xylem and the food comes down in the vessels of the phloem.

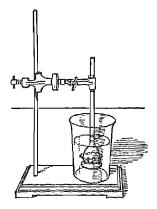
The cortex in a young root is made up of undifferentiated parenchyma cells. The cortex acts as a middleman between the vessels of the central cylinder and the epidermal cells. It passes



Root hairs on a mustard seedling. They are elongated epidermal cells that push out among the soil particles and absorb water and minerals.

on into the vessels that carry them upward the water and the minerals that the root hairs absorb. The food that comes down through the phloem diffuses outward through the cortex cells until it reaches the epidermis and the root hairs. In many roots food is stored in the cortex cells.

Absorption of water and minerals. Water and minerals pass into a root hair through the cell wall and on through the layer of cytoplasm inside the wall. The root hairs are differentially permeable, by which is meant that some substances pass through them and some do not. It is possible, therefore, for a root to take one substance from the soil and leave another unabsorbed. No complete explanation of the activity of roots can be given, but one process that goes on in them is osmosis. Osmosis is defined as the passage of a liquid or of a substance in solution through a membrane,



An experiment to show osmosis.

Demonstration of osmosis.

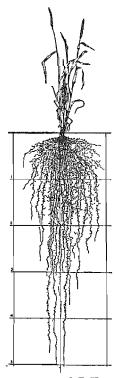
Osmosis may be demonstrated in the manner indicated in the illustration. A piece of cellophane or parchment paper is tied over the mouth of a thistle tube. Then the bulb of the tube is filled with sugar solution or molasses and the lower part of the bulb is immersed in water. Water passes into the tube and the liquid rises in the

stem of the tube. The passing of the water into the tube through the

membrane is an example of osmosis.

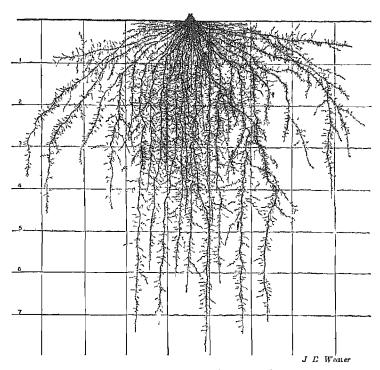
The explanation of osmosis lies in the fact that gases, liquids, and substances in solution diffuse from places of greater concentration to places of lesser concentration. Water is more concentrated in the beaker than within the thistle tube; therefore it passes through the membrane into the tube. In the same way water and mineral substances that plants require pass from the soil into the root hairs of a plant.

Extent of root systems. The total extent of a plant's root system is far greater than is usually understood. The taproot of an alfalfa plant may extend downward 10 feet, which is the reason why a field of alfalfa in our plains states keeps green when other crops are parched with drought. Corn roots extend out 4 feet in every direction from the plant and reach a depth of 6 or 7 feet. The root of a 5-year-old pear tree that blocked a 12-inch drain tile was found

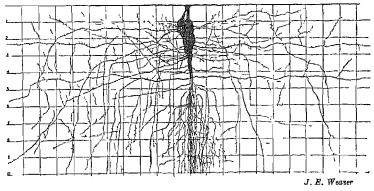


J. E. Weaver

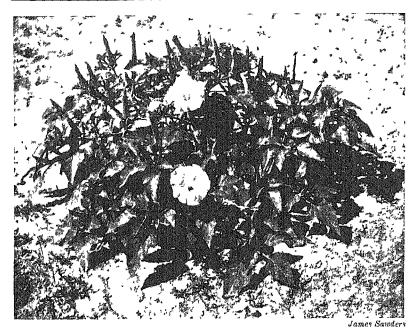
Root system of wheat plant. In this and the succeeding diagrams each square represents a foot.



Extent of root system of a corn plant.



Root systems of the bush morning-glory (see next page) of our Western plains. A single plant may draw materials from 5000 cubic feet of soil. The fleshy root at the base of the stem weighs from 10 to 20 pounds.



Aboveground portion of the bush morning-glory. Its root system, shown on the preceding page, adapts it for growth in dry soil.

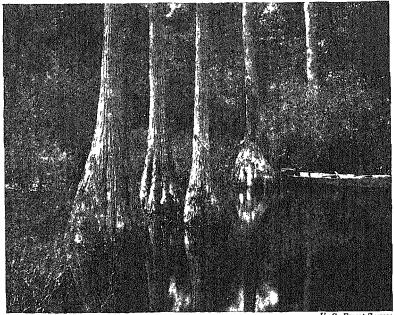
to have grown a distance of 61 feet along within the tile and to have developed a mass of rootlets that had a total length of more than 2 miles. In a single cubic inch of soil 2000 roots of Kentucky bluegrass bearing 1,000,000 root hairs were found. The combined length of the roots and root hairs in this cubic inch of soil was more than 4000 feet.

The roots and root hairs of a plant form a great system of fine filaments that pasture among the soil particles for minerals and water. They range far and do an intensive job. In a cornfield every inch of soil between the rows is filled with a cobwebby root mass.

Roots adapted to different environments. The roots of some plants can live only in well-drained soils. The roots of other plants survive and grow in the mud of ponds or marshes. Buckwheat will grow and produce a crop on heavy and undrained

soils in which carbon dioxide accumulates until the roots of wheat are killed. Some plants will flourish in acid soils and others only on neutral or alkaline soils. Some grow in salt marshes and others are killed at once by the salt in the soil. Lands should be given over to the crops and trees to which they are best suited, which means that the roots of the plants must be able to flourish in the soil in which they are grown.

An interesting experiment. In regions of heavy rainfall the soluble minerals are kept leached from the land; but where irrigation has long been practiced or where bodies of water have dried up, an accumulation of minerals is likely to ruin the land for agricultural use. In our own Great Plains, in Russia, and in other parts of the world there are hundreds of millions of acres



U. S Forest Service

Cypress trees in a Southern swamp. The roots of the cypress are adapted for growth under swamp conditions where most other trees cannot grow. The cypress and the bush morning-glory are examples of the survival of the unlike.

of such lands, and the Russian plant breeders are attempting to produce a wheat that is adapted to their salt steppes. They have crossed wheat with a perennial salt-land grass and now have a plant that combines the qualities of the two parents. Its roots will live in the salty soil and they are perennial. Year after year they remain alive and each spring send up shoots that bear heads of wheat. When the plant breeders get the best possible varieties of this wheat they hope to be able to plant with it lands that are now useless, and without plowing or sowing to be able to reap a wheat crop each year.

Such work is good work. If men would turn their real attention to such activities there could be an undreamed-of abundance in the world for all. A productive perennial wheat would stop at once all the dust storms and blowing away of the land in our plains region. If a study of roots will help us get better ones on the plants we raise, such a study is well worth while.

PROBLEM SIX

What Makes a Soil Fertile, and How Can Soils Be Improved?

"Since the achievement of our independence, he is the greatest patriot who stops the most gullies."

PATRICK HENRY

The soil is the home of plant roots. It is the reservoir from which plants draw their water and mineral supplies. Since it is not possible to appreciate the life of a land plant without some understanding of the soil in which it grows, we shall close our unit with a brief study of soils and of how from an agricultural point of view soils may be improved.

What soil is. Soil is made from the rocky crust of the earth, weathered and crumbled into small grains. Ordinarily the top soil has mixed in with it many particles of vegetable matter. This organic material is called *humus* and is the undecayed remains of plants. Growing and living among the particles of a fertile soil are countless bacteria and blue-green algae. Protozoa also are abundant in moist soils.

The character of a soil depends to a considerable degree on the rocks from which it is formed. Sandstones decompose into sandy soils and shales into clays. A sandy soil is composed of coarse particles and a clay of very fine particles. A soil of medium-sized particles or one composed of a mixture of fine and coarse particles is called a *loam*.

A soil which has been formed where it lies by the weathering and crumbling of rocks is called a *residual soil*. One that has been transported and deposited by water, wind, or glaciers is a *transported soil*.

Properties of a good soil. A good soil is one in which crop plants flourish. A poor soil is one in which these plants make only a slight growth. A soil may be poor because it fails to provide an environment in which the roots of cultivated crops can live and make a wide growth or because it does not furnish the water or the mineral supplies needed by the plants.

A soil to be suited to ordinary crop plants must be well drained and loose and granular in structure, so that the oxygen of the air can penetrate it and the carbon dioxide given off by the roots and in the decay of organic matter can escape. It must furnish an abundant water supply to the plants even in times of drought. It must provide the mineral substances that the plants require for their growth. It must not be too acid or too alkaline for the crop that is being grown. Practically always a good soil is deep; a soil in which roots can grow only in a shallow surface layer fails in time of drought.

How water is held in soil. Water is held in the crevices between the soil particles and as a film over the surface of the particles. The former is called *free water*, the latter *film water*. Free water can be drained off. When this is done the spaces among the soil particles are filled with air and the soil water supply is held as a thin layer of film water on the surface of each soil grain. The finer the grains are the more surface there is on the particles of a given volume of soil. Therefore fine soils hold more water than coarse ones.

Humus adds very greatly to the water-holding capacity of a soil, for the little pieces of vegetable matter soak up water like

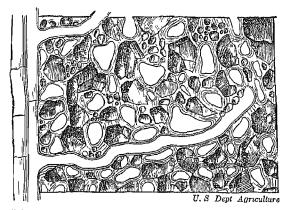


Diagram illustrating soil structure and how root hairs draw water from the soil. Each soil particle is covered with a film of water. The white areas among the soil particles are air spaces.

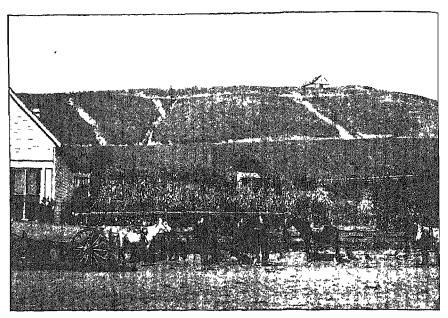
little sponges and give it up to the plant roots as the soil dries. Leaf mold from a forest will hold more than its own weight of moisture.

Minerals required by a plant. Of sixteen elements necessary for plant life, three (oxygen, hydrogen, carbon) are obtained from water or from the air. The others are nitrogen, sulfur, phosphorus, potassium, calcium, magnesium, iron, manganese, boron, chlorin, iodin, zinc, and copper. These elements the plants obtain from the soil, and a fertile soil supplies them in sufficient amounts to meet the needs of the plants. If any one of the required substances is present in only a scant supply the growth of the plant is slow.

The three elements most often lacking in soils are nitrogen, phosphorus, and potassium. In a few soils there is a deficiency of manganese, copper, zinc, or boron. To such soils farmers and gardeners add fertilizers to supply the needed elements. Fertilizers cause plants to thrive by giving them the chemical substances they need in the building processes that go on within their cells. As was explained in an earlier unit (page 24), the discovery that chemical fertilizers can be used to supplement the natural mineral supplies of soils was one of the great events in the history of mankind. We must judge the importance of events by their results.

Use of manures in soil improvement. A practice as old as agriculture is the adding of vegetable matter or animal manures to the soil. This improves the soil in three ways. By the decay of the added materials it increases the supply of minerals that are used by the plant. It increases the humus content of the soil and thus adds greatly to its water-holding capacity. It loosens the soil and allows a deeper and more complete penetration of the soil by the absorbing rootlets.

When animals feed on plant materials the carbon of the plants is released into the air as carbon dioxide. Other elements that were in the plant are in the liquid and solid wastes from the animal body. When these wastes are returned to the soil the mineral supply of the soil is not appreciably depleted. A prosper-



A view in North Carolina, showing soil erosion. Even more destructive than the washing of gullies in fields is "sheet erosion," which strips away the top soil from the entire surface of the land.

ous and permanent agriculture usually requires the keeping of both plants and animals. When plants alone are grown and the crop is removed from the soil year after year, an exhaustion of the soil in both humus and minerals results.

Soil acidity and alkalinity. Rhododendrons grow well only in acid soils. Alfalfa flourishes only in a soil that is at least slightly alkaline. Some other plant may do best in a neutral soil. Most plants can accommodate themselves to some range in soil acidity or alkalinity, but usually a plant has some point in acidity or alkalinity at which it grows best.

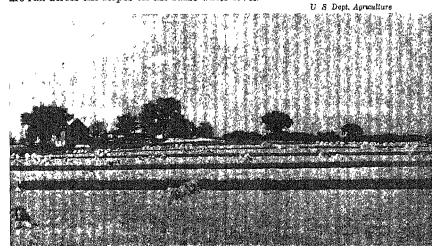
The alkaline soil elements (sodium, potassium, magnesium, calcium) are easily soluble in water. Therefore in regions of heavy and moderate rainfall these leach out of the soil and are carried away. Over much of our country most of the soils, except those formed from limestone and volcanic rock, are acid. Treatment of such soils with lime or ground limestone is extensively practiced and this treatment improves the soils for most grasses and legumes. Peat and muck are acid from the decay of vegetable matter and these materials (also ammonium sulfate)

are used to make the soils of lawns and gardens acid for the growth of acid-loving shrubs and flowers. In a garden it is easily possible to make part of the soil alkaline and part acid, so that both alkaliloving and acid-loving plants may be grown.

Importance of soil conservation. In the warm humid parts of the earth humus decays rapidly and except in swamps there is not much accumulation of it in the soil. In cooler regions there has been in places a gradual building up of the humus supply for centuries and a layer of topsoil rich in it has been formed. The prairie regions of our Middle West owe their fertility to the deep humus layer which collected in the wide marshes and lakes as the glaciers retreated to the north. Newly cleared forest lands also have unusual fertility because of their abundant humus supply.

In most places it is very important to keep the topsoil layer from washing away. Where there is only a thin layer of residual soil over a rock base (as on mountain sides) or where the topsoil is rich in humus and the subsoil sterile, this is especially important. In some places it is possible to restore the fertility of a soil by plowing under vegetable matter, but over great areas the removal of the topsoil may ruin the land for generations or for centuries. Soil conservation is therefore worthy of all the attention it receives.

Strip cropping on a Kansas farm. The bands of grass and alfalfa catch the topsoil blown or washed from the plowed portions of the fields. On hillside land the strips are run across the slopes on the same water level.



Grass as a soil conserver. The great enemy of the land is the plow. The greatest of all soil conservers is grass. Hundreds of thousands of acres of our rolling and hillside agricultural lands should be taken out of cultivation and put into permanent pasture. In many parts of our country an acre of good grassland will yield more animal food than an acre of corn or wheat and more of our livestock should be grass-reared. When land is planted to forests it is taken out of food production and devoted to the growing of lumber. Grass preserves the soil and at the same time allows the land to be used in the production of human food. The following quotation may help you to appreciate the importance of grass in nature and to us.

"Grass is the forgiveness of nature — her constant benediction... Forests decay, harvests perish, flowers vanish, but grass is immortal. Beleaguered by the sullen hosts of Winter, it withdraws to the impregnable fortress of its subterranean vitality and emerges upon the first solicitation of Spring. Sown by the winds, by the wandering birds, propagated by the subtle agriculture of the elements which are its ministers and servants, it softens the rude outline of the world. It bears no blazonry of bloom to charm the senses with fragrance or splendor, but its homely hue is more enchanting than the lily or the rose. It yields no fruit in the earth or air, and yet, should its harvest fail for a single year, famine would depopulate the world." John James Ingalls

Soil science is a great branch of scientific agriculture. In our agricultural colleges there are departments devoted to it and large textbooks treating of soils in detail have been prepared. In any region the plant side of scientific agriculture is largely a matter of fitting crops to the soil and soil to the crops. As far as possible the farmer or the gardener should select plants suited to his soil and should use measures that will improve the soil for the crops that he grows.

THE PLANT WORLD

The plant way of life began with very simple organisms. was continued in the filamentous green algae and in the larger brown and red algae of the sea. Then we find liverworts and mosses out on the land and in the ferns and their allies, land plants so large that roots are necessary and vessels must be provided for transporting food and water through the plant. nally, in the spermatophytes we find plants still more highly adapted to the land. They are covered with epidermis or cork that keeps them from drying. They have wide-reaching root systems. The trees are strong to withstand the winds, and the annual herbs in their seeds have a way of passing safely through cold and drought. In the mammals with their warm blood and their equipment of instincts and intelligence we have the culmination of the animal plan. In the seed plants with their diversified bodies, their flowers and seeds, and their storage of food we find the highest expression of the plant plan.

Many persons delight to work with and to study plants. If you are one of these, do not hesitate to follow your inclinations. Among plants as among animals the laws of biology are exemplified. In the plant kingdom you will find endless diversification and countless adaptations. Plants meet and solve the problems of individual and race survival as animals do. They live as truly as animals do and from them you can learn biology. If you like plants, you might find much happiness in a course in botany and a useful life work in the great field of applied plant biology.

Our own complete dependence on plants is apparent. Our food comes from them. They furnish us with most of our building materials and provide us with fuel. Most of our clothing comes from plants directly and the remainder from animals that feed on plants. In the manufacture of many of the new plastics, plant materials are used as a base. All the world lives on and by the products of photosynthesis, and until chemists are able to duplicate this process plants must hold a chief place in human life.

IINIT COMPREHENSION TEST

- A. What is the function of the leaf? Give two functions of stems; three functions of roots. In what two ways is the plant body controlled? Give location and description of each of the following elements of the fern stem: sclerenchyma; epidermis; fibrovascular bundle; endodermis. What are the tracheae and what is their function? How is parenchyma distinguished? Define: xylem; phloem; bast fibers; cambium; sieve tubes. Describe the formation of water vessels (tracheae) and sieve tubes. Mention two characteristics of plant cells. What is cell sap? What is a vacuole? Explain the rapid enlargement that sometimes takes place in parts of plants. How are different kinds of tissues developed in the growing parts of plants?
- B. How are the bundles arranged in a dicot stem? in a monocot stem? Describe the structure of a woody dicot stem. Describe the formation of bark. How do woody stems grow in circumference? How is an annual ring formed? How is the age of trees determined? In what ways does a herbaceous stem differ from a woody stem? Why cannot herbaceous plants attain a large size? Contrast a monocot bundle with a dicot bundle. How do the stems of monocots increase in diameter? Describe the structure and strength of the stems of grasses. To what do monocot stems owe much of their strength? Name some monocot fibers that are used by man.
- C. Describe the structure of a leaf. Why do plants require water? How are leaves adapted to their work of food making? How do leaves adjust themselves to water and light conditions?
- D. Define: primary root; secondary root; adventitious root. Distinguish between a taproot and a fibrous root. Describe the structure of a root. How are water and minerals absorbed? Define: differential permeability; osmosis. How may osmosis be demonstrated? What is the explanation of osmosis? Give examples of the extent of root systems. What adaptations to soil conditions do the roots of different plants show? How are Russian scientists attempting to produce a crop for the salt steppes?
- E. Define: soil; humus; sand; clay; loam; residual soil; transported soil. What are some important properties of a good soil? How are free water and film water held in soil? What determines the amount of water a soil holds? What elements are required by plants for growth? Which of these are most often lacking in soils? How does manure improve a soil? Why do many soils become acid? How can the acidity be remedied? Why is soil conservation so important? What plant is "the greatest of all soil conservers"?

SUGGESTED ACTIVITIES AND APPLICATIONS

- 1. Perform the experiment indicated at the bottom of page 521. If no bell jar is at hand, the tumbler or beaker that contains the cuttings may be placed in a covered glass vessel.
- 2. Bring in a half-dozen cuttings of willow as thick as your thumb and a foot long. On two of them remove a narrow ring of bark 3 inches from the bottom. On two others remove the bark in a similar manner but only halfway round the stem. Keep the other two as controls.

Set all the cuttings in a vessel and treat as in the experiment above. Results?

- 3. Rub an ointment containing a growth-promoting substance on the side of the stem of a growing tomato plant. Results?
- 4. Dig out and bring to the schoolroom a Pteris rhizome, leaving the leaves attached. With the microscope make the tissue studies suggested in the text.
- 5. Gather fresh leaves (leaves of Boston ivy will serve well). Dip the leaves in boiling water to kill them and place in water to decay. After several weeks remove the leaves and wash them gently. Press some of the skeletonized forms flat and paste them in your notebook. In woodlands in the springtime, almost perfect skeletonized leaves may be found.
- 6. Decolorize a nasturtium leaf (page 224). Then examine it with the low power of the microscope. The tracheae of the bundles may be seen as long structures with cross markings. Follow a vein out to its finest branches. How many tracheae are in it where it ends? If a nasturtium leaf is not available, use another kind of thin leaf.

Examine the inside of bark for bast fibers.

- 7. Examine the cells in the hairs on the stamens of a squash for vacuoles. Germinate peas in a pot of moist sawdust and perform the experiment indicated on page 531. Use India ink to mark off the divisions. The experiment may be performed by using the tip of a fast-growing vine.
- 8. Make diagrams showing the location of the bundles in a dicot and a monocot stem.

Examine under the microscope a cross section of wood.

9. Water well a potted plant that has a single stem. Then wrap the pot in cellophane, tying the cellophane about the stem of the plant. Weigh the pot and plant and record the weight. Set the plant in the sun and after 24 hours reweigh. The difference in the weights represents the amount of water lost by transpiration.

If a plant of this size were growing in each square foot of an acre of land and each transpired water at the above rate, how much water would be given off from the acre in a day?

10. Secure a half-dozen long-stemmed leafy shoots. (Weeds, young sunflowers, or climbing nasturtium or honeysuckle shoots may be used.) Place the shoots in water colored with red ink or a red dye, making sure that the tracheae are not blocked by air. Set the shoots in the sun.

After 20 minutes, remove a shoot from the water and split it lengthwise. What tissue is colored red? How far has the red coloring ascended in 20 minutes? Remove shoots at 10-minute intervals and examine. At what rate per hour does the water rise in the stems?

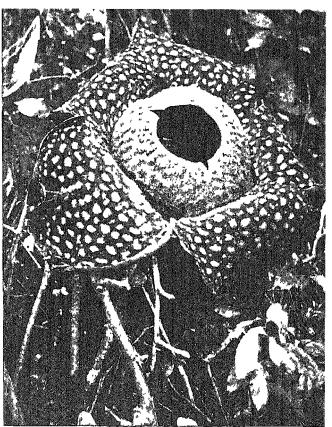
- 11. Place a shoot of wandering Jew with variegated leaves in colored water and watch the leaves.
- 12. Remove a ring of bark from a small branch of a tree. Do the leaves wilt? What does this prove?
- 13. Grow wheat, oat, or rye seedlings in a pot of earth, sand, or moist sawdust in the dark. Move to sunlight and note how long before a greenish tint begins to appear.
- 14. Split a carrot lengthwise and study its structure. Germinate mustard or radish seedlings in a covered vessel on black paper and observe the root hairs.
- 15. Perform the experiment on osmosis indicated at the top of page 546. (Note. It has recently been announced that plants do not take in soil minerals by simple osmosis, but that they expend energy and do work in taking the minerals into the roots.)
- 16. Fill a flat-sided glass jar with earth and against the wall plant corn, beans, and peas. Which grows faster, the stem or the roots?
- 17. Make small drainage holes in the bottoms of four tin cans. Number the cans. Weigh them and record the weights. Fill the cans in order with air-dried sand, clay, loam, and leaf mold. Reweigh and record the weights.

Set the cans in water and leave them overnight. Lift them from the water and allow them to drain until no more water drips from them. Reweigh and calculate the percentage by weight of water held by each kind of soil material.

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Ewing Galloway

UNIT 13

PARASITOLOGY AND PARASITES

Many small organisms gain their subsistence from other living organisms. Parasitism is a very important way of life.

"The world of parasites is a major world of life, worthy to rank with the worlds of sea, of fresh water, and of land in the number of its inhabitants and the variety of their ways of living."

H. G. Wells

THE PREVALENCE OF PARASITISM

QUESTION FOR CLASS DISCUSSION

If you had the power to eliminate one parasite from the earth, which one would you choose?

GREEN plants are independent in their nutrition. They build their own food. All other organisms are dependent. They subsist on food obtained directly or indirectly from green plants. Herbivorous animals live by feeding on plants. Carnivorous animals kill and eat other animals. Another great class of organisms (most bacteria and fungi, earthworms, ooze eaters of the sea) subsist on dead organic materials and still others live as parasites.

A parasite is defined as a plant or an animal that lives in or on another living organism and subsists on it. Parasitism is a special mode of life by which small organisms are able to turn the tables on larger organisms and use them for food. The word "parasite" (Greek para, beside, + sitos, food) means literally one that lives beside its food. The host is the food and the parasite and the host live together in close association.

Only those who have given attention to the matter understand how common and how important parasitism is in the living world. There are hundreds and hundreds of parasitic species. The organisms that are too small to be seen and resisted are often more deadly to an animal than the larger forms that prey on it. Many varieties of vegetables, fruits, and grains can be grown only in certain regions because in other areas they are subject to attacks of parasitic fungi, and plant breeders everywhere are busy trying to produce new varieties of cultivated plants that will be immune to fungus attacks. Wild animal populations are frequently greatly reduced because of epidemics of parasitic diseases. In the warmer parts of the earth the parasites that infest them are by far the greatest obstacle to the rearing of domestic animals.

Many of our own worst diseases are caused by the small onecelled parasites that we call germs, and until we learned how in a measure to control these small organisms they were the chief health hazard of man. No part of biology is of more practical importance than that which deals with the smaller organisms that have adopted the parasitic way of getting food.

Naturally, only small organisms are fitted to lead a parasitic life. The animal groups most given to parasitism are the protozoa, the flatworms and roundworms, the insects and their allies (ticks, mites), and, in the water, smaller crustacean forms. Nearly all the parasitic plants belong among either the fungi or the bacteria.

Problems in Unit 13

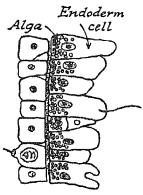
- 1 How does parasitism arise?
- 2 What important examples of parasitism do we find among the flatworms?
- 3 What important parasites are there among the arthropods?
- 4 What are some of the symbiotic relationships of the higher plants with other plants?
- 5 What minute parasites are important as causes of disease in man and other animals?
- 6 How does the animal body react to infections with bacteria?

PROBLEM ONE

How Does Parasitism Arise?

We must assume that parasitism is a secondary mode of life. The organisms that are parasites must have had ancestors that were not parasites, for in the first days of life on the earth there were no larger organisms to serve as hosts. The theory is that parasitism arises by a free-living form taking up its abode within or on a larger plant or animal and through the course of generations gradually adapting itself to the conditions of its new environment. We must assume also that the parasitic way of living has been adopted independently by many different types of organisms. Only by this assumption can we explain the facts that parasites belong to so many different phyla and that many of them are closely related to forms that are not parasites.

Associative living. Many pairs of organisms live in a close association that is not parasitism. Hidden among the gills of oysters small crabs are often found. Worms live within the shells of clams. Sea anemones ride around on the backs of crabs, and barnacles often attach themselves to fishes or other sea



Section through the body wall of a green hydra, showing small one-celled green alga cells within the animal cells.

animals. In a lichen, a fungus and an alga live together in still closer association; and there are green sponges, green hydras, green corals, and green worms, in all of which one-celled green algae live mixed in among the animal cells or even within the animal cells. Some of these associations are mutually advantageous. In some, one organism gets protection within the other or obtains a better food supply because it is carried about. All of them are examples of the living together of two organisms without one being parasitic on the other.

Associative relationships. The study of the relationships of organisms that live together is of especial interest to many persons and in your reading you will doubtless find discussions of these associations and references to them. The terms and definitions given below will perhaps help you in your reading and thinking in this field.

When two organisms live together the association is called symbiosis (sı̃m'bı̃-ō'sı̃s; Greek syn, with, + bios, life; life with or together). The associated organisms are called symbionts.

If the symbionts live together without either one feeding on the other they are *commensals* (Latin com, with, +mensa, table) and the association is commensalism. The two commensals eat together at the same table, but neither eats the other. The oyster crab and the oyster are commensals. Poison ivy and the tree on which it climbs are commensals.

When the symbionts benefit each other — as the plant and animal cells in a green hydra do — there is *mutualism*. The relationship to each other of termites and of the protozoa that digest the wood which the termites eat is one of mutualistic symbiosis (page 214).

When the advantages of the association are all one way the relationship is one of *helotism* (hěl'ot-ĭz'm; from *Helot*, a Greek slave); one organism holds the other in slavery. A honeysuckle plant (or a grapevine) and the bush it overgrows furnish an example of helotism. The climbing plant enslaves the one that supports it.

When one symbiont feeds on the other the association is *parasitism*. An organism that lives in or on another and derives its nourishment from the other organism is a *parasite*. An organism that supports a parasite is a *host*.

A parasite that lives on the outside of the body of its host is an *external parasite*. A parasite that lives within the body of its host is an *internal parasite*. Ticks and lice are examples of external parasites. Intestinal worms and disease germs are internal parasites.

As you will note, these classes of relationships are not exclusive



Dodder, a member of the morning-glory family, which grows as a tangle of fine yellowish vines over other plants. It has lost its chlorophyll and has become parasitic on the plants about which it twines. (See page 582.)

of each other. An organism that lives with another, no matter what the relationship, is a symbiont. A commensal may be living in a relation of mutualism or of helotism. By far the most common symbiotic relationship is parasitism.

Development of parasitism. The two characteristic features of the parasitic relationship are that the parasite lives in close association with (on or in) its host and that it depends on the host for food. Let us consider some ways of living that may help us in imagining how free-living independent organisms might make the transition to a parasitic life.

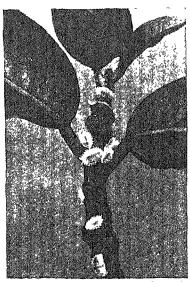
1. Parasitism through food relationships. Many insects are bloodsuckers and many others live on plant juices. Suppose such insects had poor wings and therefore remained at all times near their food supply. From such food habits there might develop external parasites of the type of fleas and plant lice that are able to crawl about but yet live on their hosts. Suppose an organism settled down in one place with its beak thrust into its

host. It would then be a parasite that lived as the ticks and scale insects live.

No sharp line can be drawn between small animals like mosquitoes and biting flies, that return again and again to feed on a living victim, and the ones we class as undoubted parasites. We speak of the flea as a parasite, but a flea may leave its host and return to it again. The mites that suck the blood of chickens at night, although they spend the days on the roosts, are called parasites. It seems reasonable to believe that many external parasites are small forms that have developed the habit of staying at all times with the organisms on which they feed. Their dependence on the larger organism for food has led them to live in close association with it.

2. Parasitism through shelter relationships. It is easy to see how parasitism might develop out of commensalism. The little

crabs within the oyster might come to depend on the oyster for food, and the clam worm might become parasitic on the owner of the shell in which the worm sought shelter. There are little flatworms and crustaceans that are parasitic in the gills of fishes, and a small parasitic worm is the usual cause of the formation of a pearl in an oyster. These parasites probably are examples of small animals whose ancestors at first sought shelter within the larger organisms and then found it possible to get their food supply also from the larger forms. The dependence on the larger organism for shelter leads to a dependence on it for food also.



Bureau of Entomology and Plant Quarantine

Mealy bugs on croton. They crawl about in early life and then become attached to the plant. They have become parasitic through a food relationship.



Slender Gerardia, a facultative parasite. The Gerardias are fineleaved members of the snapdragon family that grow wild over most of the eastern part of the United States. They may grow either independently or as parasites on the roots of other herbs.

3. Parasitism through other associations. Small organisms like bacteria, protozoa, and some of the parasitic worms are brought into association with their hosts in various ways. They may be swallowed in food or water. Some of them are injected into the bodies of larger organisms by biting insects. Many kinds of bacteria live as saprophytes on the skins and in the respiratory and alimentary tracts of the higher animals. In various ways minute organisms are brought into close association with larger ones. and many cases of parasitism have developed out of these associations. The small organisms develop the adaptations necessary to allow them to live within the bodies of the larger forms.

Obligate and facultative parasites. Parasites that have become so specialized and delicate that they cannot exist in the outside world are called obligate parasites — parasites obliged to follow a parasitic mode of life. Organisms that can live either in the body of the host or in the outer world are facultative parasites. The tetanus bacillus is an ex-

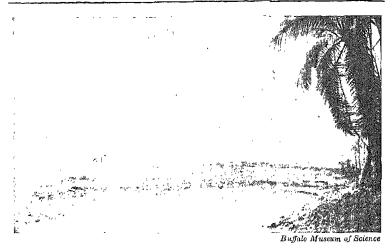
cellent example of a parasite of the facultative kind. It can grow in rich soil, it is common as a saprophyte in the intestinal contents of horses and other animals, and it can live as a parasite in a wound. It is only partly committed to a parasitic life. A number of bacteria of this type grow on the human skin. Ordinarily they exist as harmless saprophytes, but if the skin is broken they may become parasitic in the wound. Among the bacteria a series of forms can be selected that show every degree of transition from a saprophytic to a parasitic life.

Well-adapted and ill-adapted parasites. A well-adapted parasite is one that is able to feed on its host without causing serious damage. It allows its host to live on and provide it with a continuous supply of food. A parasite that causes the death of the host before the parasite has made much growth is not well adapted to the life it leads, for if the host dies the parasite must perish also. The kinds of germs that cause mild chronic infections are much better-adapted parasites than the ones that cause short, severe illness. A notable example of a poorly adapted parasite is the diphtheria germ, which is seldom able to make more than a small patch of growth before its virulent toxin has disabled the host.

We often speak of parasites as "enemies" of the organisms on which they subsist, but this conception of the relationship of the parasite to the host is misleading. To the parasite, the host is a food supply and not something to be harmed. The relation to us of the germs that cause our illnesses is much the same as that of plants to the soil of a garden or of a paramecium to a pool. The germs merely use us as a food source and when they make us ill they harm themselves as well as us.

Restricted and special life of parasites. Many parasites are almost strangely restricted in their choice of hosts. Out of hundreds and hundreds of organisms that might serve them as hosts, most parasites can grow in only one. Generally speaking, the bacterial and protozoan diseases of the different kinds of animals and plants are caused by different kinds of germs. The fungi that grow on the apple are different from those of the lilac or potato. The intestinal worms are to a large degree different in the different hosts they infest and the germ of human malaria is a different species from the germ of bird malaria.

This restriction to one or to only a few related hosts, coupled with the difficulty of making the transfer from host to host, has led many parasites into most unusual life ways. The story of the malaria germ with its double life in man and the mosquito is a strange tale. The tapeworms are a group of fantastic animals, each species having two hosts and a wholly different kind of life



A coral reef. All the reef-building corals have, as mutualistic partners, green algae that live within their cells. These corals can live without eating, and all around the earth they are very important in the shallow waters of the warmer oceans (pages 802~804).

in each host. To have a proper outlook on the materials of this unit from a biological point of view, you must look on parasites as organisms that are specialized to an extreme degree.

Our conclusions in regard to parasitism are (1) that it arises by a small organism becoming dependent on a larger one for food and protection, and (2) that the development of parasitism is favored by any conditions that cause a small and a large organism to live in close association. These conclusions are inferences drawn from many separate facts. The study of the next problems will help you to judge whether the conclusions are correct.

PROBLEM TWO

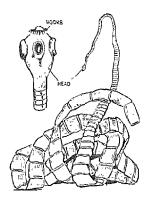
What Important Examples of Parasitism Do We Find among the Flatworms?

The parasitic flatworms include the tapeworms and flukes. With only a few unimportant exceptions they have alternate hosts. As some of the fungi grow first on one kind of plant and then on another, so these worms pass back and forth between two different animals.

The tapeworms. The tapeworms are all parasitic. Some of them are microscopic and some are 30 feet in length. In its adult form the tapeworm lives in the intestines of one host; its early life is passed in the muscles, brain, liver, or other internal part of the other host. We shall begin the life history with the adult form that is found in the intestinal tract.

The head of the worm is armed with six small spines, or hooks, by which it fastens itself to the intestinal wall. In the region back of the head, the body grows and as it grows it is cut into segments by cross walls. Segment after segment is formed until in some species the body may be several feet or yards in length. Each segment has its own "kidneys" (nephridia) and has both male and female reproductive organs. As the segments grow older they increase in size and become practically filled with masses of fertilized eggs. Finally they break off and pass out of the intestine, each segment carrying within itself hundreds of eggs.

The tapeworm has no mouth and no digestive tract. It simply absorbs nourishment from its host. It has a very feeble muscular system. Its inert life calls for practically no movement. Its nervous system is almost nonexistent. It has no eyes, no ears, no intelligence. It is an extreme example of the degeneration that goes with parasitism. The one feature in which it is highly developed is its reproductive capacity. The number of eggs produced is enormous. Probably not one of the eggs in a million has a chance to develop, but they are produced in such numbers that the race survives.

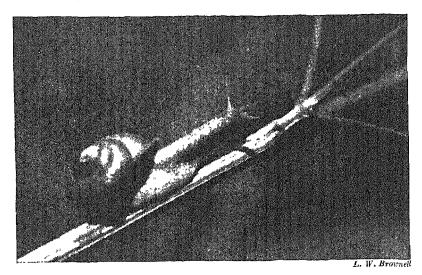


A tapeworm. New segments are continually formed back of the head and the old segments break away as they mature.

If an egg is swallowed by the alternate host it hatches in the intestine. The young tapeworm bores through the intestinal wall and is borne away by the Then it settles down somewhere (in the muscles, brain, liver, eye) and develops into a form that has a head, and back of the head a bladder (or cyst) filled with liquid. This form of the tapeworm is called a cysticercus (sis'ti-sur'kus: plural cysticerci). One of them can be seen with the naked eye. "Measly" pork or "measly" beef may be studded with them. If a cysticercus is swallowed by the other host the young worm is released in the intestine, takes hold, and

grows into the segmented worm. The body, like a ribbon or tape, floats free in the intestine and each segment gets its nourishment by absorbing the food digested by the host.

One kind of tapeworm that is found in the human intestine has the cow as the alternate host; another, the pig. Human beings may become infested with these by eating insufficiently cooked pork or beef. Another tapeworm has as its hosts cats and mice, the cats becoming infested by eating the mice. One kind that is troublesome to poultry keepers alternates between the hen and the housefly, and another kind between hens and snails. There are tapeworms that pass from wolves to rabbits, from dogs to fleas, from geese to water fleas, and from men and dogs to fish. A disease of sheep called "gids" or "staggers" is caused by the development in the brain of the cysts of a species of tapeworm that has the dog as its other host. There are hundreds of kinds of tapeworms and the alternate hosts of many of them are not known. In dealing with them the important point is to break the life cycle where they pass from host to host. By thoroughly cooking beef and pork, human infestation can be prevented.



Snails are hosts of many species of tapeworms that infest hens and other domestic animals, and the pond snail is the alternate host of the liver fluke of sheep. It is sometimes necessary to keep poultry and sheep away from snail-infested land to break the life cycle of the parasites that prey on them.

The flukes. The flukes are small flatworms that live attached to the gills of fish, tadpoles, and salamanders, on or within toads and frogs, or in the bodies of higher animals. The only one of any importance in our country is the liver fluke, which is found in the gall bladders of pigs, cows, and sheep and occasionally in the gall bladder of man. It has a mouth at the front end, and two suckers by which it clings to its host.

In our country the liver fluke is important chiefly because it causes disease in sheep. It has an alternation of generations between the sheep and the pond snail. The egg of the worm develops in the snail and grows into a mass of tissue which breaks into many tiny, free-swimming forms. These attach themselves to stalks of grass, and sheep become infested by eating vegetation in the margins of ponds or on low ground where snails live.

In some parts of the Orient fluke infestation of human beings is a serious health problem. A species of liver fluke reaches its human host from raw fish. A fluke that lives in the intestine is swallowed in vegetables and a lung fluke is eaten in crabs and crayfish.

Prevalence and seriousness of worm infestation. No groups of multicellular animals are so given to parasitism as are the flatworms and roundworms. Their small size and their soft, elongated, flexible bodies fit them for a parasitic existence. They are injurious not only because they use the host's food supply and irritate the nervous system by their presence and movements, but also because they secrete toxins. In all the warmer parts of the earth parasitic worms are a very serious cause of ill health and lowered vitality in both man and domestic animals.

In dealing with these worms the important point is to break the life cycle where they pass from host to host. Note that in the forms with alternate hosts infestation of one host comes from swallowing the egg and of the other from eating the first host. By thorough cooking of meats human infestation with tapeworms and trichina can be prevented.

We have said that parasites are highly specialized animals. To give point to this statement we will mention one of the special adaptations of the intestinal worms. These worms have in their bodies substances that protect them from the digestive enzymes of their hosts and thus keep them from being digested. The immunity, however, is specific and does not protect them against all enzymes, as is shown by one method of destroying them. Pineapple and some figs contain protein-digesting enzymes, and the raw juices of these fruits are used in some countries as worm remedies. They kill the worms by digesting them as they would any other proteins. In the whole animal realm there are no more striking examples of special adaptations to environments and ways of living than are found among the parasitic worms.

PROBLEM THREE

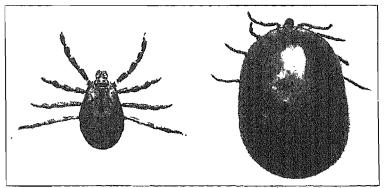
What Important Parasites Are There among the Arthropods?

The arthropods, as is natural in so great a group of small animals, have among them many parasitic forms. In the sea, infestation of fishes and other larger animals with small crustacean parasites is common. On land numerous species of insects are parasites during the whole or a part of their life cycles. Among the ticks and mites parasitism is the common mode of life.

TICKS AND MITES

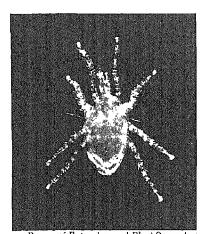
The ticks and mites belong to the Arachnida and are relatives of the spiders. In them the head and thorax are fused. The body has two parts instead of three, as in an insect, and there is no external sign of body segmentation. They are particularly abundant in the warm parts of the earth. The ticks are of especial importance because of the diseases they transmit.

The ticks. The ticks cling by their strong head parts to larger animals and suck blood. In time the female becomes filled with eggs and distended until, like the mature segments of a



U. S. Dept. Agriculture, Bureau of Entomology and Plant Quarantine

A tick before feeding and the same tick after it has filled itself with blood. A young tick can take enough food at one time to last it for several months.



Bureau of Entomology and Plant Quarantine mite that was removed from a

A mite that was removed from a beetle. Bees, grasshoppers, and many other insects are attacked by these small parasites.

tapeworm, she is little more than a bag of eggs. Then she drops off her host and lavs from 2000 to 4000 eggs. Young ticks ("seed ticks") hatch from these. After hatching they climb up on the grass or weeds and wait (if need be for several months) until there comes along a cow, dog, or other animal to which they can attach themselves. After attaching itself to a host a young tick feeds and grows for a time and then drops off to moult. This it does twice before it takes the adult form and is ready to settle down for its last feeding.

One kind of tick in our Southern states is the alternate host of the germ of Texas fever, a disease of cattle. This tick, along with the disease that it carries, has been eradicated in most areas by killing with dips and sprays the ticks that were attached to cattle and by removing all cattle from infested land until the ticks perished of starvation. Another species of tick found both in our Eastern states (especially in the South) and in the West carries the germ of tick fever ("spotted fever") and by its bite communicates the disease to man. In western Africa ticks are particularly abundant, collecting on the wild grazing animals in immense numbers and spreading several diseases of animals and men.

The mites. The mites attack both animals and plants. The poultry-house mite hides on the roosts and in crevices, and at night sucks the blood of the hens. Another mite is parasitic on the grasshopper. One kind, the itch mite, burrows like a little mole through the human skin, laying its eggs in the tunnel as it goes and causing the "seven-year itch." Still another, the follicle mite, enters and lives in a hair follicle (usually on the nose or face) and causes blackheads,

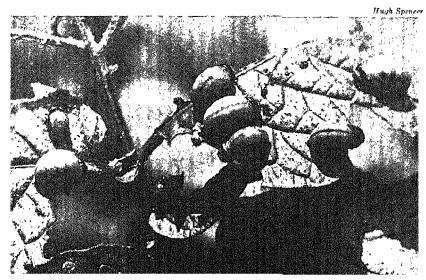
The mites, as well as the ticks, are very tenacious of life. Some of them can survive without eating for three or four years. There are many mites that live on plants, among them being the leaf-blister mites of the pear and apple and the rust mite of the orange. The harvest mites ("chiggers," "red bugs") are a family that live primarily on plants, but if the larvae get on a person they burrow into the skin. Their attacks can be prevented by dusting sulfur or powdered naphthalene inside the clothes. After they attach themselves they can be killed by treating the bites with alcohol, ammonia, or a weak solution (1 or 2 per cent) of carbolic acid.

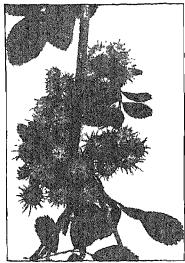
PARASITIC INSECTS

Some insects are parasitic on animals and some on plants. A few (fleas, lice, scale insects) are parasitic during their whole existence, while many others are parasitic only during the larval stage. The parasitic insects are very important because of both their injurious and their beneficial effects.

Insects parasitic on plants. We do not always think of plant lice, borers under the bark of trees, and maggots ("worms") in fruits as parasites, but they fall under the definition of parasite

Larvae of the Colorado potato beetle. They are external parasites on the potato and related plants.





Nature Magazine

Galls on a rose branch. They are caused by the sting of a fly, and a larva of the fly grows in the center of each gall.

given on page 562. Among the insects whose larvae live within the tissues of plants may be mentioned the codling moth, which is a foremost apple pest; the curculio, which infests the fruit of plums and peaches; the squash borer; the corn borer; the cottonboll weevil; and the bean, pea, and other weevils, the larvae of which grow in nuts and plant seeds.

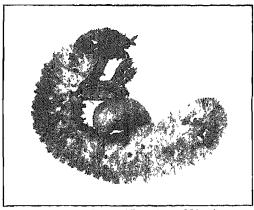
An interesting group of insects that are parasitic on plants are the gallflies, for whose larvae plants provide not only food but homes. The eggs are laid in the tissues of stems or leaves and in some way the plant cells are

stimulated so that they grow into abnormal structures called galls. These are common on the stems of weeds and on the leaves of oaks and other trees, and strange red galls with finger-like projections are found on the leaves of the rose. The galls on each species of plant have a definite form. Within a gall at the right season you will find the small white larva of the fly.

Insects parasitic on animals. The tachina flies lay their eggs on the backs of caterpillars, and the larvae develop and kill the caterpillars by feeding on them. The ichneumon flies drill through the bark of trees and logs to deposit their eggs in wood borers. The warble fly pierces the skin on the back of a cow, deer, or rabbit with its ovipositor and lays an egg. The larva that hatches from the egg feeds on the tissues of the host and grows into a large grub in a burrow under the skin. When it is ready to pupate it emerges, falls to the ground, and goes into its resting stage in the earth. The next summer it appears as a mature fly. The horse botfly fastens its eggs to the hairs on the

front legs or breast of a horse, and if an egg is swallowed by the horse the larva attaches itself to the stomach wall and grows as a grub ("bot") in the horse's stomach.

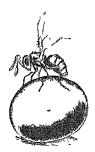
The parasitic wasps are a group of insects that deserves special mention. Some of them place their eggs beneath the skins of caterpillars. Some dig in

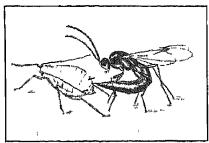


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Larva of a wasp parasitic on the grub of a Japanese beetle. The adult female wasp digs down through the earth to the grub and lays its eggs on it. How the wasp knows where to dig we do not know.

the earth until they find the grubs of other insects and lay their eggs in these. There are hundreds of very small species, ranging in length down to $\frac{1}{25}$ th of an inch, that deposit their eggs in small insects or in insect eggs. Some of these species develop to adult form in from 7 to 10 days, and an adult female may attack 100 host insects. They multiply so rapidly that sometimes in late summer





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A tiny wasp laying its egg in the egg of another insect and (right) another wasp parasitizing a plant louse. The parasitic wasps are among the most important of the natural checks on other insects.

the great majority of all the aphids (plant lice) or scale insects on a plant will be found to be dead from the little wasp larvae within. One species of these small wasps is known to attack the eggs of more than 150 kinds of other insects and in late summer more than 90 per cent of the eggs of some species may be destroyed by this parasite. It is easy to understand that insects of such habits may be very important in holding other insects in check.

In the adult stage such insects as we have mentioned above live independently, but in the larval stage they are true parasites. The change in the mode of life is appropriate to the change from larval to adult form. The adult is fitted for active life and can forage for itself.

If the pupae or cocoons of parasitic wasps and other insects are gathered, sometimes an insect of a kind we are not expecting comes out of it. A little wasp may come from the pupa of a parasitic fly, or one kind of wasp from the cocoon of another species. The explanation is that the parasite has itself been parasitized. A secondary parasite has made the primary one its prey.

PROBLEM FOUR

What Are Some of the Symbiotic Relationships of the Higher Plants with Other Plants?

This study will not include the relationships of the higher plants to the parasitic fungi (page 294) or to the bacteria that cause plant diseases. It will be limited to a discussion of seed plants that are themselves parasites and to the relationships that seed plants have with some forms of bacteria and fungi that are of advantage to both organisms.

PARASITIC SEED PLANTS

In forest mold the roots of different plants grow interlaced with each other and a woody vine may clasp the stem of a bush or

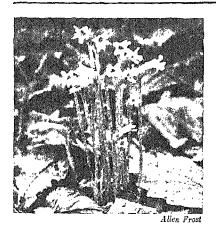
a sapling until it lies in a spiral groove. Yet only in the rarest cases is the relationship between plants above the thallophytes a parasitic one. There are no parasitic mosses, ferns, or gymnosperms, and only a few examples of parasitism are found among the flowering plants.

Root parasites. Under beech trees and in pinewoods you will find little brownish plants that are called "beechdrops" and "pinedrops." They have no chlorophyll, but grow on the roots of the beech and pine trees and draw their nourishment from them. There are also, both in our own coun-

Beechdrops. The beechdrops are parasitic on the roots of beech trees. They are brownish in color, from 6 inches to 2 feet in height, and in late summer bear purple and white striped flowers.



Allen Frost



Broom rape, a plant that lives parasitically on the roots of many herbs. It is from 3 to 8 inches tall and the white or violet flowers appear in the spring. A relative of broom rape, the cancerroot (Conopholis), is parasitic on the roots of oaks. It is a brownish, scaly little finger-shaped

plant, 3 to 6 inches high.



Allen Frost

False beechdrops (right), a plant that has lost its chlorophyll but is not a parasite. Like its relative, the Indian pipe (page 299), it lives as a saprophyte on dead vegetable matter. It would not be a great step for a plant like this to become parasitic on the roots of other plants.

try and in Europe and tropical countries, other species of flowering plants whose roots tap the roots of other plants for a food supply. The plant that produces the largest known flower (Rafflesia) is a root parasite on a species of grape in the Malayan forests. It has no leaves and produces the huge stemless flower (3 feet across) shown on page 561.

Parasites of aboveground parts. The best known parasitic seed plant is the dodder (Cuscuta) or love vine (page 566). It grows as yellowish patches of vines in fields of clover, alfalfa, lespedeza, or other plants. Its seed germinates in the earth and at first the young plant has its own roots and lives independently. If, however, it can find the right host plant it twines about it and attaches itself to it. Little projections grow from the dodder vine into the host plant and draw the nutriment from it. Then the roots of the dodder die and it lives entirely as a parasite on the other plant. If the dodder does not find a host before the food that was stored in the seed is entirely used, it dies. Doubt-

less the dodder's ancestors at one time were green vines that made their own food, but now it has lost its chlorophyll and can exist only as a parasite.

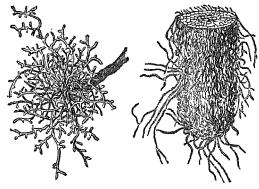
The common mistletoe is an example of a partial parasite. Its seed is deposited by birds on the branches of trees. A seed germinates and the root of the young plant penetrates the wood of the tree and taps its water supply. The mistletoe develops its own leaves and makes its own food. It uses the roots of the tree to gather its water and minerals and the stem of the tree as a support to hold it up to the light. It takes the raw materials from the tree rather than the finished product as true parasites do. Among the hosts of the mistletoe are the oak, sycamore, apple, and mesquite. There are species of mistletoe that have no chlorophyll and are complete parasites.

MUTUALISTIC RELATIONSHIPS OF SEED PLANTS

Many seed plants have symbiotic relationships with fungi and bacteria that are of mutual aid. Two of the most important of these relationships will be discussed.

Root fungi. There are scores and hundreds of species of forest trees and of other forest plants that have fungi growing in close association with their roots. These fungi are called *myco-*

rhiza (mī'ko-rī'za; Greek mykes, fungus, + rhiza, root). They grow wrapped about the small rootlets of the plants and penetrating their outer layers, and the relationship between the higher plant and the fungus is one of mutualism. The mycorhiza function as long

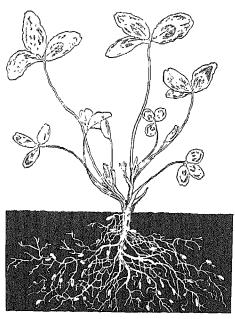


Mycorhiza on the root of an oak and of a beech. The relationship between the fungus and the tree is one of mutualism. (After Frank.)

root hairs, absorbing water and minerals from the soil and passing them on into the plant root. In return they share the food that comes down into the root from the leaves of the plant above. Most mycorhiza are facultative parasites, being able to live alone in the rich forest loam; but both the fungi and higher plants are benefited by the symbiotic association.

One difficulty in transplanting forest plants is that the mycorhiza may not be able to grow in the soil of the garden or lawn in which the plant is set. It is often helpful if a quantity of woods soil is placed about the roots of the plant in its new location. Some plants cannot live without their fungus partners on their roots.

Nitrogen-fixing bacteria. Certain kinds of soil bacteria take nitrogen from the air and fix it in compounds. They grow among the soil particles, feeding on the organic matter, and they



Nodules on the roots of a clover plant. The bacteria that live in these nodules are helpful to and are helped by the higher plant.

take free nitrogen from the air and build it into amino acids and proteins. Just as a green plant has the power to take carbon from the air and build it into sugar and starch, so these bacteria have the power to take nitrogen from the air and build it into the proteins which are necessary for growth and tissue repair.

Some of the nitrogenfixing bacteria have learned to live in the roots of legumes (e.g., clovers, alfalfa, peas, vetches, lespedezas, soy beans). In suitable soils the bacteria grow alone to some extent, but if legumes are planted the bacteria move into the roots and flourish greatly. They get carbohydrate from the legume and then by fixing nitrogen they build a rich protein supply. If you examine the roots of legumes you will find on them little swelled nodules, or balls, where the bacteria are growing. The root cells multiply as though a diseased condition had been caused and build the tumor-like nodules, but the partner-ship is beneficial to the green plant. In a field of soy beans or sweet clover a plant that has missed getting any bacteria in its roots may be yellowish, while close to it the plants that have nodules will be larger and a much richer green. The legume absorbs part of the protein that the bacteria build.

Farmers "inoculate" the seeds of some of their legume crops with cultures of nitrogen-fixing bacteria to make sure that the right bacteria will be present when the plants start to grow. Sometimes a farmer cannot raise a profitable crop of a legume, not because his soil is not suited to the crop but because it is not suited to the nitrogen-fixing bacterium that goes with it. It is customary to speak of legumes as improvers of the soil, but certainly a part of the credit for soil enrichment should go to the bacteria that work as their small aids.

It has been announced that bacteria cultivated from the large nodules on the roots of a soy-bean plant fix nitrogen and manufacture amino acids very rapidly. The bacteria from the small nodules carry on this process very slowly or not at all. Some of them are mere boarders in the soy-bean roots—parasites in the full sense. Doubtless in the future legume seeds will be inoculated with bacteria that have been selected for their protein-building power.

The seed plants are as a group large and complex organisms, and naturally it is difficult for them to adapt themselves to a parasitic existence. Of all those in our country, only the dodder has any economic importance as a parasite. It is sometimes troublesome, but there are many worse weeds.

PROBLEM FIVE

What Minute Parasites Are Important as Causes of Disease in Man and Other Animals?

Nearly all the pathogenic (disease-producing) microscopic parasites that infect animals belong among the bacteria, the protozoa, or the viruses. Yeasts and small fungi cause a few animal infections, but as animal parasites they are relatively unimportant. Popularly we speak of disease-producing parasites that are too small to be seen by the naked eye as germs; a disease germ is a minute parasite that causes illness in its host. The table on page 587 shows a list of important germ diseases and the group to which the organism causing each disease belongs.

THE PATHOGENIC BACTERIA

Bacteria are all about us in the world. They have definite forms and we can study them under the microscope. When they make the transition from a saprophytic to a parasitic life they do not change their form but simply move into the body of the host and grow among the host's cells. The fact that bacteria are visible under the microscope and the further fact that nearly all kinds of them can be grown in cultures in the laboratory have aided us greatly in gaining an understanding of them and of the diseases that result from infection with them.

How bacteria cause disease. Some bacteria cause illness by the production of *toxins* (poisons). Diphtheria or tetanus germs growing in a culture give off into it toxins of unbelievable potency. Only snake venoms can be compared to these poisons in their injurious effects on human cells. When toxin-producing bacteria grow as parasites they cause illness of the host by poisoning its cells.

Other pathogenic bacteria that do not produce free toxins are believed to form poisonous compounds (endotoxins) that are released when the bacteria die and their cells are broken down. Any foreign protein is injurious in the animal body, and when there is a heavy bacterial infection many of the invaders are

SOME PARASITIC DISEASES

	BACTERIAL	PROTOZOAN	Virus
Human dis- eases	Tuberculosis Pneumonia Typhoid fever Appendicitis Tonsillitis Diphtheria Whooping cough Gonorrhea Cholera Bubonic plague Tetanus	Malaria African sleeping sickness (Trypanosomiasis) Kala-azar Amebic dysentery Syphilis Chagas disease Yaws Oriental sore	Common colds Smallpox Infantile paralysis Influenza Rabies Yellow fever Encephalitis (Sleeping sick- ness)
Diseases of domestic animals	Contagious abortion (cows) Tuberculosis Foot rot Anthrax Tetanus Glanders Infectious mastitis (cows) White diarrhea (chicks) Horse distemper	Fowl coccidiosis Black head Texas cattle fever Bird malaria Nagana (Trypanosomiasis) Surra	Canine distemper Hog cholera Fowl pox Horse influenza Foot and mouth disease Rabies Pleuropneumonia Rinderpest (Cattle plague) Encephalomyelitis (horses)
Plant dis- eases	Pear blight Brown rot (tomatoes, potatoes, egg plants) Wilt diseases Potato stem rot Cabbage black rot		Yellows (affecting many plants) Mosaic diseases (affecting many plants) Peach-leaf curl

destroyed and their broken-down remnants are released in the body of their host. The exact way in which the bacteria of many infections cause illness is not yet understood, but in general it may be said that in these infections substances are released that poison the host cells.

Specialization of pathogenic bacteria. Like most other parasites, the pathogenic bacteria are highly specialized. Most of them are obligate parasites. They can be grown on specially prepared culture media and some of them can grow in

milk or remain alive for a time in water, but most of them are not fitted for free life in the outdoor world. They infect all the larger animals, and generally speaking any one variety or strain is limited to a single host. Human beings, chickens, horses, and dogs each have their own lists of disease-producing kinds. Some forms grow in only one tissue, as for example the lungs or the skin.

There are, however, kinds of pathogenic bacteria that are not so highly specialized. The germs that cause tuberculosis, undulant fever, and septic sore throat in man infect cows also. The plague bacillus attacks rodents as well as man, and man contracts tularemia (a bacterial disease) from the rabbit. Most of the bacteria that cause human diseases live by being passed from person to person, but some of them are not restricted to human hosts.

Adaptability of bacteria. If cultures of pathogenic bacteria are grown for a long time in the laboratory they may lose their power to cause disease. They become adapted to growing as saprophytes and lose the adaptations that made them able to grow as parasites. Bacteriologists speak of such cultures as attenuated. An attenuated strain of germs is one that has lost in part or wholly its disease-producing power.

On the other hand, when bacteria are passed rapidly through a succession of animals of the same kind — one animal being inoculated from another — the virulence is often heightened. The germ becomes better adapted to the conditions in the animal's body. There is developed in the germ a better adaptation to a parasitic life. The changes in the organism are explained on the assumption that certain individuals as they divide change in a way that adapts them better to their life conditions. There may be as many generations of bacteria in a day as there are generations of men in a thousand years; so there is opportunity for quick change.

Experimental studies of parasitic microörganisms lend support to the idea that parasites are the descendants of free-living forms. In the laboratory these minute beings are capable of quick change and of developing adaptations to the particular conditions under which they grow.

THE PARASITIC PROTOZOA

Among the important pathogenic protozoan forms are the ameba

which causes dysentery in man; the coccidia which attack many animals; the malaria organism which infects not only man but many birds; and the trypanosomes. The latter are slender forms that live in the blood. They are the cause of the African



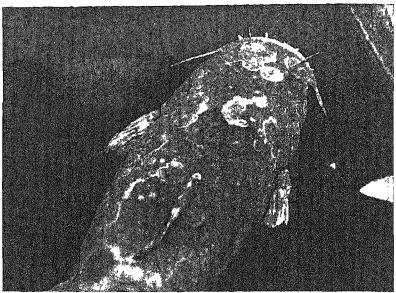
Trypanosomes from the blood of a camel.

sleeping sickness in humans and of animal diseases (surra, nagana) that in parts of the tropics make the keeping of cattle and horses very difficult.

Transmission of protozoan disease. Some of the pathogenic protozoa, as the ameba of dysentery and the coccidia, gain entrance to their hosts through the mouth. Many others have the ability to live in both a vertebrate and an insect host. Insects are carriers of these organisms and man becomes infected from insect bites. You are familiar with the way malaria is spread by mosquitoes. In the tropics many protozoan diseases of both man and other animals are transmitted by mosquitoes, flies, or other biting insects. It seems remarkable that a parasite should be able to adapt itself to two different hosts so distantly related as a mammal and an insect, but many protozoa have made this adaptation. In many of the protozoan diseases of man and the higher animals the germs live in the blood, which makes it certain that they will be transmitted to an insect that lives by sucking blood.

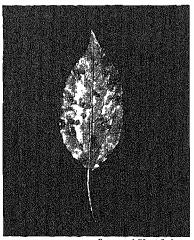
Menace of protozoan infections. There are vast fertile areas of the earth that are practically without human inhabitants because of insect-borne protozoan diseases. There are great parts of Africa where the keeping of the larger domestic animals is impossible because of protozoan parasites transmitted to them from wild animals.

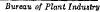
A few years ago a species of African mosquito carrying a par-

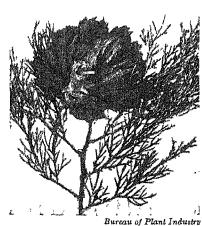


S C Dunton, New York Aquarium

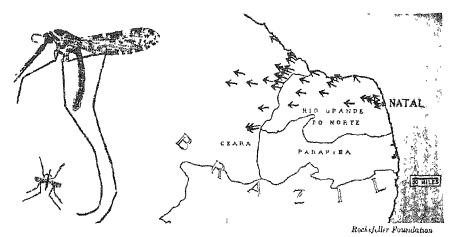
A catfish with a fungus infection of the skin. Goldfish very commonly suffer from fungus attacks, and there are a considerable number of human diseases of the skin and lungs that are caused by fungi.







Leaf spot on an apple leaf, and a cedar apple caused by the same fungus on a cedar tree. The fungus spreads by spores and alternates between the cedar and the apple. Parasitic fungi are discussed on pages 294–296.



The mosquito invader from Africa and the spread of the deadly form of malaria which it introduced into Brazil.

ticularly deadly form of malaria was introduced (probably by airplane) into Brazil. The infection spread, and in the area it reached in the first years 10 per cent of the human inhabitants died and 90 per cent were on relief. There is danger that this mosquito and the germ it carries will spread over all the warmer parts of the Americas. If it should be introduced into the populous region of southern Asia and the adjacent islands the results would be appalling. Rapid travel has greatly increased the dangers from the parasitic protozoa that are insect-borne.

THE FILTERABLE VIRUSES

Viruses are invisible under a microscope and until recently could not be grown in the laboratory as bacteria are. It has been very difficult, therefore, to study the virus diseases and to work out methods for their control. Now two recent discoveries are causing our knowledge of viruses to make a great advance. It has been learned that many viruses, if they are injected into a developing hen's egg, will multiply greatly in the cells of the embryo chick. It has been found that by the use of high-speed centrifuges they can be extracted in highly concentrated form



Lederle Laboratories, Inc.

Inoculating partially incubated eggs with the virus which causes encephalomyelitis (blind staggers) in horses. The virus multiplies in the chick embryo and from the embryos a vaccine for immunizing horses against the disease is made.

from tissues that contain them. Some of the facts that have been learned about the viruses are set forth on page 286.

Virus infections. The filterable viruses often grow within the cells rather than among them. They cause a long list of plant diseases (e.g., mosaic diseases, vellows) and in animals they attack especially the skin, mucous membranes, and nerve tissue. Some of the viruses are less restricted as to hosts than most of the parasitic bacteria and protozoa. rabies virus, for example, can grow in practically any mammal. The virus of many plant diseases can infect more than one species of plant. The smallpox

virus will grow not only in man but also in the cow and the rabbit, and some of the viruses that cause diseases of domestic animals and birds (e.g., foot-and-mouth disease, encephalomyelitis of horses, parrot fever) may cause disease in man also.

Many of the virus diseases of both plants and animals are spread by insects. Yellows in plants is carried by leaf hoppers. Yellow fever and fowl pox are mosquito-borne. Encephalomyelitis of horses is believed to be spread by the bites of flies or mosquitoes, and several virus diseases are communicated to man and other animals through the bites of ticks and lice.

Control of virus infections. The most important method of controlling virus diseases of crop plants is the use of seed free from infection. A few virus infections of animals have been controlled in certain areas by exterminating the insect carriers, but the greatest success against these diseases has come through the preventive method of vaccination. After an attack of many of the virus infections of animals the host becomes immune to further attacks. By vaccination with weak germs or dead germs it is possible to build this immunity to some infections without an attack of the disease.

Smallpox vaccination has long been practiced.



View in the incubator room of the laboratory where the vaccine for immunizing the horses is prepared. The trays of eggs are placed on a carrier which takes them to the room where they are inoculated. They are then brought back to the incubator room on the other carrier.

Vaccination against rabies and yellow fever is effective. A method of vaccinating against typhus fever has been announced. and vaccines for the protection of farm animals against a number of virus diseases are regularly employed. Some of these viruses withstand long drying. Many of them are carried by insects that are at present beyond control except in cities. Some insects become infected from wild animals and this complicates the problem of control. It is hoped that new methods will enable scientists to work out vaccination methods against many virus diseases, among them influenza and colds.

Mutations in viruses. Recently it has been reported that by laboratory treatment the viruses can be easily changed and that the diseases caused by these changed forms differ from the diseases caused by the original strains. It is believed also that in nature the viruses are constantly changing. Some scientists believe that there has recently been a mutation (change) in the virus of equine encephalitis that makes it dangerous to man, and that the explanation of epidemics of influenza may perhaps be that especially virulent strains of the viruses appear The molecules of many organic compounds from time to time. are very large and chemists modify them endlessly by detaching from them atoms or groups of atoms or by making additions to them. The viruses seem to be giant molecules that, while they retain their general character, can be changed in their details.

In attempts at the control of diseases of men and domestic animals that are caused by microörganisms, two great general methods are followed. The first is to block the transmission of the parasite from host to host. The second is to raise the resistance of the host by vaccination or other methods until the parasite cannot harm it. By destruction of insect vectors (carriers), by providing pure water supplies and safe methods of sewage disposal, by pasteurization of milk, and by quarantine and other public health measures, the incidence of many diseases has been greatly reduced. By immunization of the hosts other diseases have been brought or are being brought under control.

PROBLEM SIX

How Does the Animal Body React to Infections with Bacteria?

In parasitism two organisms are concerned — the parasite and the host. Large animals like man always play the part of host, and in cases of infections with microscopic organisms they develop defenses against the small parasites that prey upon them. Because what understanding we have of these protective methods has to a large degree been gained by a study of bacterial infections, this problem will be in the main a study of how the higher animals resist bacteria. The animal body defends itself against them through the activity of the white blood corpuscles and by the production of substances that kill the germs or otherwise help to hold them in check.

Defense mechanism. In many infections the larger white corpuscles of the blood (also the endothelial cells of the lungs and of the linings of the body cavities) engulf and digest

the invading germs. This process is called phagocytosis (făg'o-sī-tō'sĭs). The cell that does the eating of the germs is called a phagocyte (Greek phago, to eat). The white corpuscles are free to move to any part of the body and they gather wherever there is infection. They creep out of the blood capillaries and devour the germs that are growing among the cells. Substances which cause the cells to take up germs may become more abundant in the blood during an attack of a disease. These substances are called opsonins. The opsonins have been compared to the sugar and cream that we put on our breakfast foods. germs more appetizing to the white corpuscles.



A white corpuscle engulfing a bacterium. Without direction from the nervous system, these small soldiers of the animal body attack and destroy microscopic foes.

They make the

Lysins are substances in blood which dissolve or digest the germs. They appear or increase in amount when there is infec-

PARĀSITISM

tion, and usually even in illness they keep the blood free from germs and so prevent the spreading of the infection to new parts of the body. In cases of blood poisoning (septicemia) the lysins fail to do this and the germs are then able to set up their growth all through the body. In some diseases the chief defense of the body seems to be the phagocytes and in others the lysins.

Antitoxins are substances which neutralize the toxins produced by microörganisms. An antitoxin does not kill germs, but it protects the body from their toxins until the germs can be disposed of in other ways. The opsonins, lysins, and antitoxins taken together are called *immune bodies*. They are the substances that give us immunity to infectious disease.

Immunity. Immunity is the capacity to resist germs. It may be natural or acquired. It may be active or passive. All natural immunity is active. Acquired immunity may be either active or passive.

Natural immunity is inborn. We are naturally immune to the germs of practically all plant diseases and of nearly all the diseases of other animals. We are not afraid of catching distemper from dogs or bronchitis from chickens, for we have substances in our bodies that prevent these germs from growing in them.

Acquired immunity is gained after birth. Naturally we have no immunity to measles or smallpox, but we can gain this immunity by successfully passing through an attack of the disease. We can gain immunity also against many diseases by vaccination or by the use of antitoxins or other sera.

Active immunity is immunity in which the body manufactures its own defense substances. In active immunity the body makes its own opsonins, lysins, and antitoxins and does its own fighting of the germs.

Passive immunity is immunity acquired by the use of second-hand immune substances — substances obtained from the blood of another person or the blood of an animal of another species. In passive immunity the body does not make its own defense substances but passively receives them. Passive immunity against some diseases may be conferred by blood transfusions



This kitten was the smallest and weakest of a family of four, but it proved immune to a distemper-like disease that carried away its more vigorous brothers and sisters. It had a natural immunity to the germs of the disease.

from another person or by the injection of animal blood sera (diphtheria antitoxin, antipneumococcic serum) that contain immune bodies.

Immunity through vaccination. The great method of artificially building up active immunity is by vaccination. In vaccinating against smallpox, cowpox virus is used. This is a strain of the smallpox germ that has had its power to produce disease in man attenuated by growth in the body of the cow. For inoculation against typhoid fever, dead germs are used. In diphtheria immunization there is injected a toxin (toxoid) in which the poisonous end of the toxin molecule has been destroyed, while the part which causes the development of the antitoxin is retained.

The advantage of vaccination is that we can gain through it the same immunity that an attack of the disease gives without having the disease. Vaccination with cowpox germs causes the same immune substances to be formed that appear during an attack of smallpox. Inoculation with dead typhoid germs causes the same immune bodies to appear that an attack of typhoid fever would bring out. Injection of diphtheria toxin brings protective antitoxins into the blood. Because of the new discoveries concerning filterable viruses, vaccination will probably be more and more used.



Collecting venom from a snake. By injecting the venom in gradually increasing doses into the blood of a horse, an antivenin is prepared. The antivenin is a serum and when used in cases of snake-bite it confers a passive immunity.

Strictly applied, the word "vaccination" (Latin vacca, cow) refers only to inoculation with cowpox; but it has come to have a much wider use. It is used to mean the injection of any kind of material that causes the development of substances that protect against the iniected material. Vaccination is employed not only against many kinds of disease germs, but also in cases of hay fever. asthma, and food allergy (page 640).

The materials that are injected into the

body in vaccination are called *vaccines*. The substances that are formed in response to the injection are as a class called *antibodies* (Greek *anti*, against). Immune bodies are antibodies formed in response to the presence of disease germs or their products in the body. Other antibodies are formed when there is vaccination with other substances. The immunity acquired through vaccination is active immunity. By vaccination the body is stimulated to produce substances for its own defense.

Immunity by use of sera. There is a second artificial way of acquiring immunity. Passive immunity against some diseases can be conferred by the use of a serum that contains immune bodies. Diphtheria antitoxin is the most commonly used serum and it is prepared in the following manner:

Repeated doses of diphtheria toxin are injected into a horse and this causes antitoxin to appear in the blood. Then the

horse is bled and the blood is allowed to clot (page 486). The serum that gathers about the clot contains the antitoxin. If such a serum is injected into a person ill with diphtheria, the antitoxin in it will mite with and neutralize the diphtheria toxin and save the cells from poisoning. The one important point in the use of antitoxins in cases of diphtheria and other diseases is to employ them early. As soon as the toxin unites with the cells the damage is done. Sera with antitoxins in them are commonly spoken of as antitoxins.

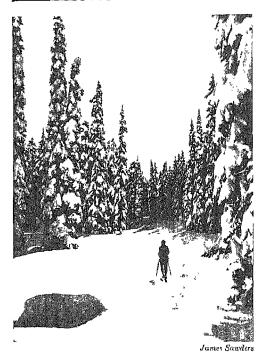
In medicine a number of antitoxins made from the blood of animals are used and antivenins (venin, venom, poison) for use in cases of snakebite are also produced. Sera for killing germs are not so successful as the antitoxins, but a germ-killing serum is extensively employed in pneumonia cases and a number of diseases are treated with human convalescent sera. Such sera are made from the blood of persons who have recovered from the diseases that are being treated. They contain lysins that will help get the germs under control.

The distinction between a serum and a vaccine should be noted. A serum is prepared from the blood of an immune person or animal and contains an antibody rather than a substance that will cause an antibody to be formed. A serum confers passive immunity. A vaccine is given to induce active immunity.

Active and passive immunity contrasted. Active immunity requires time for its development. The antibodies in a case of illness or after vaccination appear only gradually and there is usually little response before a week or ten days at least. Hence the development of active immunity by vaccination is used chiefly for prevention of disease rather than in its treatment. However, in a number of slow diseases vaccination is employed as a part of the treatment.

Passive immunity, on the other hand, can be conferred very quickly. Immediately after injection into the blood, the antibody is ready to go to work. Antitoxins and other sera are therefore much used in the treatment of persons after they become

PARASITISM



Recent experiments have shown that animals raised in a constantly warm atmosphere have less resistance to germs than ones exposed part of the time to cold. There is reason to believe that the coolness and sunshine of the outdoors raises immunity.

sick. They are also used to give a quick immunity to persons known to have been exposed to certain infections.

Another distinction between active and passive immunity is that active immunity is more or less permanent while passive immunity is always transient. Against some diseases (as colds) active immunity lasts for only a few months: against other infections (as smallpox, measles) it may endure for a lifetime. Cells that are once started in the production of antibodies

against these germs seemingly keep it up indefinitely. In contrast, in passive immunity the immune bodies disappear in a few weeks at most.

Personal hygiene and immunity. Against some diseases (as smallpox, measles) we have little if any natural immunity and good health is no protection against attacks of such diseases. Indeed, in preventing any of the diseases that run a quick course, good health and general personal hygiene seem quite ineffective; typhoid fever and pneumonia attack the strong as readily as they do the weak. "Without infection there is no protection" is probably true for any disease for which immunity must be acquired.

On the other hand, in overcoming germs after they have started to grow in the body — in developing the antibodies upon which acquired immunity depends — there is every reason to believe that personal hygiene and vigorous health play a great part. Good food, sunshine, fresh air, rest, and sleep have all been found highly important in building up the resistance in tuberculosis and there is no reason to believe that they are not equally important in raising the immunity to other infections. Especially in an infection of a chronic type, where it is possible to get the defensive forces of the body into action and hold them in action over a long period of time, hygiene can be used to raise the acquired immunity to its full height.

An important recent medical discovery is that heat treatment may very definitely raise the resistance to certain germs. A "fever box" is now a part of the equipment of many hospitals.

Immunity by use of medicines. It is possible to produce immunity to certain germs by the use of drugs. Quinine has long been used in the prevention and treatment of malaria and a new drug (atebrine) promises to be much more effective. Salvarsan and related compounds in concentrations that human cells can endure are fatal to the germs of syphilis and of a tropical disease called yaws. Sulfanilamide is effectively used in treating infections with many kinds of bacteria. Another drug (sulfapyradin) gives great promise in the treatment of pneumonia. Iodin, hexylresorcinol, and mercurochrome are helpful in keeping germs from growing in a wound.

Some of these drugs act by stimulating the production of defensive substances. They do not themselves kill the germs, but they stimulate the body to do it. Others, although they do not kill the germs, prevent their growth and thus hold the germs in check. Others of them are differential poisons. They are more poisonous to the germs than to their hosts. They themselves poison and kill the germs.

Examples of differential poisons that are used to control larger organisms are rotenone, which is poisonous to insects but not to higher animals and is used in sprays; red squill, which is poisonous

PARASITISM



Coker Pedigreed Seed Co

One row was planted with a strain of cotton susceptible to wilt. The others were planted with seed from a strain selected and bred for wilt resistance. In plants, as in animals, there are natural susceptibilities and immunities to parasitic organisms.

to rats but not to poultry, dogs, and cats; and copper compounds, which will kill the algae in a pool without injuring the other plants. Among the tens of thousands of known compounds there are probably substances that would control all infectious diseases. What is lacking is money and men to test them and find the ones that will do the work.

Immunity to animal parasites. The higher animals may develop a certain immunity to protozoan and worm parasites. They seem, however, to be less successful in killing these animal parasites than they are in dealing with many kinds of bacteria. A person may be infected with malaria germs for years and in many animal diseases the parasites stay in the body as long as the animal lives. It appears to be possible to develop some immunity to toxins produced by intestinal worms, but there seems to be no such thing as developing immunity against the organisms themselves. For this reason vaccination and treat-

ment with sera are not used in the prevention and cure of diseases caused by animal parasites. Our greatest success in these infections has been with drugs.

Immunity in plants. Among plants, as in animals, some species or some varieties or individuals of a species will be attacked by a disease and others will be immune to it. A fungus will grow on one variety of wheat or berry and not on another. Some kinds of pears and apples blight and others are much more resistant to blight. Rots attack some kinds of peaches and cherries much more than they do others. Plants differ in their natural immunities, and among the qualities that breeders are constantly seeking in new varieties is the ability to resist diseases.

Of the way immunity is produced in plants we know practically nothing, nor do we know how to raise a plant's immunity. We try to combat parasitic plant diseases by breeding plants that are naturally immune to the parasitic organisms and by killing the parasites with poison sprays and with dusts before they gain entrance to the host plants.

Our knowledge of microscopic parasites and of the reaction of the animal body to them is far from complete. We do not know how to prevent the spread of many infections. We know little of how antitoxins and lysins are produced. Our knowledge of the effects on immunity of light, food, and muscular exercise is scant and not exact. Effective vaccines and sera for use against many important diseases have not yet been developed.

There is, however, no reason for discouragement. A century ago no one knew of the existence of disease germs. As recently as fifty years ago we had no knowledge of immune bodies. Science marches on and much additional knowledge of immunity will soon be ours.

THE IMPORTANCE OF PARASITISM AND OF PARASITE CONTROL

This brief study can give you only a glimpse of the great subject of parasitism, yet it is enough to reveal to you its importance. The world would be a very different place for man if there were no parasites in it. It would be very different for most other organisms of any size if they could be freed from the necessity of playing host to smaller forms. Since man has learned in part to hold in check his own parasites and those of his animals and plants, the human population of the world has enormously increased. Great further advances in better human living lie just ahead through more effective parasite control.

One impressive aspect of the subject is the complexity of the forms and life relationships of many parasites. Numbers of them present problems so obscure that no understanding of them at all could be gained until they were studied in a scientific way. Therefore our knowledge of parasites is mostly of recent origin. The people of the Middle Ages had no thought of a connection between the plague ("black death") which ravaged them and the presence of rats and fleas. Until comparatively recently no one thought of malaria as having anything to do with mosquitoes. Even yet no one knows how some parasitic diseases (as encephalitis, influenza) are spread, and the alternate hosts of many tapeworms and parasitic fungi are unknown.

Great as are the triumphs that modern biology has achieved in the field of parasitology, the work of controlling the organisms that interfere with the health and welfare of man is far from finished. The elimination of certain parasites of domestic animals and cultivated plants would remake the agriculture of parts of our country. The control of human parasites would open vast new regions for human settlement. It would lift from human beings a large proportion of their ailments and free them from much of the pain they now undergo. The wide field of parasitology still offers unlimited opportunities for useful work.

UNIT COMPREHENSION TEST

- A. Define: symbiosis; symbiont; commensalism; mutualism; helotism; parasite; internal parasite; external parasite. How is it believed that parasitism develops? What is an obligate parasite? a facultative parasite? When is a parasite well adapted or ill adapted? Explain why a parasitic life is a specialized one.
- B. What variation in size is there among tapeworms? Where is the adult life passed? Where is the early life passed? Describe the adult worm. Describe the cysticercus stage. Give the complete life history of the tapeworm. What animals are alternate hosts of two kinds of tapeworms that infest man? How does infestation with them take place? What pairs of hosts do some other tapeworms have? Describe the flukes. Which one is of importance in this country? Give the life history of the liver fluke when it infests the sheep. Where are flukes a serious health problem? How are parasitic worms adapted to a parasitic existence? How do they injure the host? Why are intestinal worms not digested by the enzymes which digest food?
- C. Give the life history of a tick. Mention two diseases that are communicated by ticks. Describe the mites and their ways of living. Mention some insects that are parasitic on plants. Describe the egg-laying methods of some of the parasitic flies. Why are the parasitic wasps important as a check on other insects?
- D. Name some of the seed plants that are parasitic on the roots of other plants. Describe dodder and tell how it attaches itself to its host. If a young dodder plant does not find a host, what happens to it? How does the mistletoe obtain water and food? Describe the relationships of mycorrhiza and nitrogen-fixing bacteria to their hosts.
- E. To what three groups do nearly all pathogenic microscopic parasites belong? Name some diseases caused by organisms of each of the groups. How do bacteria cause sickness? What is the evidence for the statement that the pathogenic bacteria are specialized and adaptable? Name some important protozoan diseases. Tell about the invasion of Brazil by the mosquito from Africa. How are viruses now cultivated? What method promises to give us control of virus diseases?
- F. Define: phagocytosis; phagocyte; opsonin; lysin; antitoxin; immune body. Distinguish between natural, acquired, active, and passive immunity. What is the chief method of building active immunity? What materials are used in vaccination? Define: vaccine; antibody. How is passive immunity conferred? Contrast active and passive immunity. Explain the effects of personal hygiene on immunity. How do drugs restrain the growth of germs?

SUGGESTED ACTIVITIES AND APPLICATIONS

- 1. List as many pairs of symbionts as you can. Indicate in each case the relationship existing between the members of the pair.
- 2. Certain strains of rats have been found that live on a diet that contains no vitamin B₁. It has been found that these rats have in their intestines bacteria that synthesize the vitamin. What relationship exists between the rat and the bacterium?
- 3. The reef-building corals grow to a depth of only about 300 feet. Account for this fact.
- 4. A small roundworm lives in the water in pitcher-plant leaves and subsists on the insects and other small organisms trapped in the leaves. What special adaptation must the worm have to live thus?
- 5. Plant seeds of dodder in pots that contain several kinds of green plants. Plant one pot in which the young dodder plants are given only a small dead branch from a tree on which to climb. Watch the seedlings.
- 6. If the increase in thickness in the tick shown on page 575 was proportional to the increase in length and breadth, how greatly did it increase in volume by the feeding?
 - 7. Look for evidences of parasitism on caterpillars.
- 8. Bring in leaves or stalks of plants that show mildews, rusts, or smuts.
- 9. Look for beechdrops, pinedrops, and broom rape. In the Sierra Nevada mountains a small seed plant called the "snow plant" (Sarcodes) grows parasitically on fungi in the ground in pine forests.
- 10. In water from an aquarium or protozoan culture look for bacteria. Use the highest power of the microscope and cut the light down. The bacteria will appear as very small transparent bodies. They are so transparent that they are usually overlooked.
- 11. Carefully remove a white clover plant or other legume from the soil. Wash the roots and examine the nodules. Crush a nodule and examine the material. Can you find the bacteria?
 - 12. Make culture media and grow bacteria.

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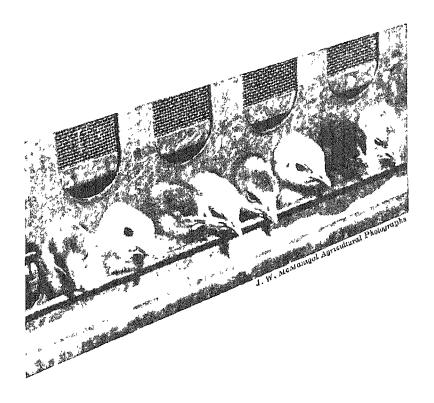
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UNIT 14 NUTRITION

Differences in nutritional requirements and processes result in a nutritional balance in the world of life,



"Life does not break any of the laws of chemistry and physics. It employs them all. But it supplements them. It directs energy into new channels."

SIR OLIVER LODGE

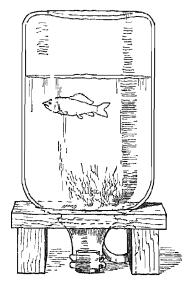
THE NUTRITIONAL RELATIONSHIPS OF LIVING THINGS

OUESTION FOR CLASS DISCUSSION

If all animals were removed from the world, would green plants necessarily disappear?

THE nutritional processes of different classes of living things supplement each other in such a manner that a nutritional balance exists among them. The green plants build; animals and colorless plants (fungi and bacteria) break down. At first it might seem that animals and colorless plants are mere parasites on the green plant world. The simple experiment indicated in the illustration below will show that in the nutritional cycle these destroyers also play their part.

The fish alone in the tightly stoppered bottle would soon die from lack of oxygen and food. The plants alone would quickly exhaust the carbon dioxide and mineral supplies of the water. To-



gether both the fish and the plants survive. Their combined life processes make up a complete nutritional scheme. The wreckers supply the builders with raw materials that enable them to keep on with their construction work.

Our subject in this unit is the nutritional processes of plants

A microcosm ("small world"), demonstrating the nutritional relationship of green plants and animals. The animal lives on the food the plants build and uses the oxygen they release. The plants use the carbon dioxide given off by the animal and the minerals in its wastes.

and animals and how the nutritional processes of green plants and of other organisms supplement each other. The unit will in the main consist of a study of plant and animal nutrition. Much of it will be in terms of chemistry, because all the processes relating to the making and using of foods are chemical processes and present-day studies of nutrition are wholly from a chemical point of view. It is not intended that the formulas given in the first two problems shall be memorized. The purpose in introducing them is to show how out of a few kinds of atoms giant molecules and almost numberless compounds can be built.

For two reasons no attempt will be made to hold the study within narrow limits. The first reason is that a real appreciation of nutritional relationships is not possible without a wide knowledge of nutritional processes. You can easily commit to memory the statement that there is a nutritional balance in the world of life, but unless you understand how plants and animals live the statement will have little meaning for you. The second reason is that nutrition is a very practical subject. A discussion of vitamins and human dietetics is included in the unit because a knowledge of these is not only scientifically enlightening but also of great practical worth.

Problems in Unit 14

- 1 What is there that is distinctive in the chemistry of living things?
- 2 What are some of the most important chemical building processes carried on by plants?
- 3 How do living things use foods?
- 4 What is the role of the vitamins in animal nutrition?
- 5 What principles and rules can be used for guidance in the selection of a human diet?
- 6 What effects have alcohol and habit-forming drugs on the metabolism and the health?

PROBLEM ONE

What Is There That Is Distinctive in the Chemistry of Living Things?

The chemistry of living things is called *organic chemistry* — the chemistry of organisms. It is a chemistry of carbon compounds. Protoplasm, cell walls, foods, enzymes, and hormones are all compounds of this element. One distinctive feature of organic compounds is that the molecules of many of them are of immense size. A molecule of common salt consists of two atoms. A water molecule consists of three atoms. The molecules of some of the carbon compounds may contain hundreds or even thousands of atoms. We shall now see how these giant molecules are built.

A simple carbon compound. Marsh gas or the "fire damp" of coal mines is a simple carbon compound. Chemists call it methane. Its formula is CH₄. Its graphic formula, or the

diagram that chemists draw to represent its molecule, is H-C-H.

The molecule consists of a carbon atom with four hydrogen atoms attached to it.

Note that the carbon atom holds in combination four hydrogen atoms. It takes on this number because it has a valence (vā'lens) of four; it has four of what chemists speak of as valence bonds. The chlorine atom has only one valence bond — it holds in combination only one hydrogen atom. When it unites with hydrogen it forms H–Cl. Oxygen has two valence bonds and holds two hydrogen atoms. When it unites with hydrogen it forms H–O–H. "The carbon atom has four hands and it wants each of them to be held." So it attracts and holds four hydrogen atoms to make the molecule CH₄.

Building bigger molecules. Suppose we remove one H hydrogen atom from a methane molecule. We then have H-C-H This is an incomplete molecule, what chemists call a radical.

One bond of the carbon is unsatisfied — one hand has nothing to hold.

Now suppose we have another similar radical, -C-H. Is there

any reason why the two radicals should not join together — why the two carbons should not hold each other's hands? There is not, and they do join to make a molecule of the gas, ethane. Its

graphic formula is H-C-C-H. It is of course a heavier gas than H H

methane; its molecules contain more atoms. The simple formula for ethane is C_2H_6 .

It is possible to remove a hydrogen atom from ethane and thus

form the ethane radical, H-C-C-. Then if we unite a methane

radical with this we have propane, C_3H_8 . Its graphic formula is H H H

H-C-C-C-H. Propane is a constituent of natural gas. It is

sold as "bottled gas" for lighting and cooking in suburban and country homes.

By adding more and more methane radicals and increasing the number of carbon atoms in the chain, larger and larger molecules are built. The first compounds formed are gases. Then come liquids — naphtha, gasoline, kerosene, fuel oils, and lubricating oils. Next come semisolids like vaseline, and finally we end with paraffin or asphalt. In a molecule of paraffin there may be as many as thirty carbon atoms in the chain.

New kinds of molecules by substitution. Examine the graphic formulas below. If one hydrogen atom is removed from methane and a chlorine atom is substituted for it, the compound is methyl chloride. This is a gas used in refrigerators.

ннн

If two hydrogen atoms are replaced by chlorine, the compound is called methylene chloride. It is a gas of no particular use.

If chlorine is substituted for three of the hydrogens, chloroform is the product. This is a volatile liquid used as an anesthetic in hospitals. If all four hydrogens are displaced by chlorine, the result is carbon tetrachloride (tět'ra-klō'rīd), CCl₄. This is a liquid used in fire extinguishers and as a cleaning fluid. Sometimes it is introduced into soaps.

You will readily see the possibilities of building many different compounds by substitutions in molecules that have long carbon chains.

The alcohols. A prominent radical in all chemistry is the -O-H radical. It is the oxygen atom with only one hydrogen atom attached and one of its bonds unsatisfied. It is water with one of the hydrogens removed. The -O-H radical is the alkali radical. It is this radical that neutralizes acids; it is the -O-H radical that makes substances basic or alkaline. Chemists call this radical the *hydroxyl radical*.

Suppose we remove one hydrogen atom from methane and

substitute for it the hydroxyl radical. Then we have H-C-H.

This is methyl alcohol, or wood alcohol.

Suppose in the ethane molecule we substitute for a hydrogen an

hydroxyl radical. We have H-C-C-H. This is ethyl or common grain alcohol.

Propane has three carbons in its molecule and if three hydroxyls

are substituted in its molecule for hydrogen we have $\begin{array}{ccc} O & O \\ H & H \end{array}$

This is trihydroxypropyl alcohol. The common name for it is glycerin. There are many heavier alcohols that have as their bases longer carbon chains.

Fats and oils. Plants and animals build up compounds that are called *fatty acids*. Below is the graphic formula of the molecule of one of these, oleic (o-le'ik) acid. It consists of a long chain of carbon atoms with hydrogen atoms and a few oxygen atoms attached; its simple formula is $C_{18}H_{31}O_{2}$. Fats and oils are made by substituting the radicals of these fatty acids for hydrogen in the glycerin molecule.

FORMULA FOR OLEIC ACID

Suppose a hydroxyl is removed from the fatty acid, as indicated by the dotted line around the -O-H in the formula above. We then have a fatty acid radical with an unsatisfied bond. And suppose three hydrogens are removed from the glycerin molecule, as indicated in the diagram on the left below. There is then opportunity for three fatty acid radicals to join the glycerin radical, as indicated in the formula on the right. This is the formula for olein, which is a liquid fat (oil) and is the main constituent of olive oil. As you will see, the olein molecule is of very large size. Its simple formula is $C_{57}H_{104}O_{6}$.

FORMULA FOR GLYCERIN

FORMULA FOR OLFIN

There are many other fatty acids in addition to oleic acid. Among these are palmitic acid, stearic acid, and butyric (butĭr'ĭk) acid. When these unite with the glycerin radical they make the fats palmitin, stearin, and butyrin. Palmitin and stearin are white solids at ordinary temperature and are the main

constituents of tallow and lard. Butter is composed mainly of these same two fats, but contains also about 8 per cent of butyrin.

Chain and ring compounds. In some organic compounds the carbon atoms are in a straight line or chain. These are called chain compounds. All the compounds we have thus far studied are of this class.

In other classes of compounds the carbon atoms are in a ring or, if the molecule is large, in a number of rings linked together. The formula below will give you an idea of the structure of the molecule of a ring compound. It is the formula for thyroxin, the hormone produced by the thyroid gland. Many organic substances belong to the ring compound class.

FORMULA FOR THYROXIN

Characteristics of organic compounds. Studies like these could be continued indefinitely, but the knowledge you have now gained will give you some idea of the distinguishing characteristics of organic compounds. All organic compounds contain energy. All of them will burn — oxidize — with the release of heat and light. Also, they are all carbon compounds. In the molecules the carbon atoms are arranged in chains or rings. It is possible for the molecules to be of great size because the carbon atoms cling to each other with a part of their valence bonds and with other bonds hold attached radicals or the atoms of other elements. The properties of organic compounds depend not only on the kinds of atoms of which they are built, but also on the number of atoms in the molecule and on the way the atoms are built together. It will be evident to you that by attaching secondary side chains to the atoms of the original carbon chain or

ring, great branching molecules of gigantic size can be built. Such molecules we find only in living things and in the chemical compounds that they build. The formula for gliadin (glī'a-dĭn), a protein found in wheat, is $C_{685}H_{1068}O_{211}N_{196}S_5$. How many atoms are in this molecule?

Perhaps it should be added that organic compounds are labile (Latin labilis, movable, fluid) compounds. They are compounds that can be easily transformed. By shifting about the atoms and groups of atoms in the giant molecules of these compounds, chemists create almost countless new substances, and in a living organism there is a complexity of rebuilding processes which is beyond our imagination to conceive. Day and night the chemical reactions within the living cells go on — transformations of the food substances, the building up, the breaking down. The fundamental life processes are the same in all organisms, but each species has other processes peculiar to itself. Each fruit or flower builds the flavor or perfume characteristic of itself. Life arises from and is supported by the swirl of chemical activity within the cells.

PROBLEM TWO

What Are Some of the More Important Chemical Building Processes Carried on by Plants?

Green plants are the supreme chemists. They are the food makers for all living things. From carbon dioxide and water and from soil minerals they build the substances that are worked over to make all the almost countless compounds that we find in the living world. Moreover, in the compounds that green plants build, they store the energy by which all life is sustained. With our knowledge of chemistry we can now discuss in more detail the building processes carried on by plants.

Photosynthesis. In photosynthesis sugar is formed from carbon dioxide and water (page 192). Light falls on the chlorophyll, a chemical reaction takes place, and sugar is the product. In the process carbon from the air is built into organic molecules. The energy of the sunlight is stored in the molecules as chemical energy.

Photosynthesis is the primary building process of the living world — the foundation process where the chemistry of life begins. All other building processes are secondary. All the carbon in all the almost countless organic compounds found in plants comes from sugar molecules that have been worked over and transformed into these substances. All the energy used in these secondary building processes and in the plant's life processes is from the supply stored in photosynthesis and released by oxidation within the cells. Animals, too, live and grow and carry on their activities by the use of energy that was stored in photosynthesis. The energy in all fuels and all foods was stored in photosynthesis.

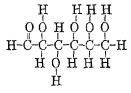
Polymerization and polymers. Much of the secondary building in plants is done by a process that is called *polymerization* (pŏl'i-mer-i-zā'shun; Greek *polys*, many, + *meros*, part). In the process two or more molecules of a substance, without being broken down, are linked together to form a larger

molecule. The more complex substance thus formed is called a *polymer* of the simpler substance out of which it is built.

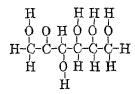
An example of polymerization is the formation of the solid substance called paraform from the gas formaldehyde. Three molecules of formaldehyde (CH₂O) combine to form one molecule of paraform (C₃H₆O₃). Paraform candles are sold for use in fumigating; when they are lighted the heat breaks up the paraform molecules again into formaldehyde gas.

The sugars. The sugars, with the starches, belong in the group of compounds that are called carbohydrates. They consist of carbon, hydrogen, and oxygen, and the hydrogen and oxygen are in the same ratio as they are in water (two atoms of hydrogen to one of oxygen). The sugars are polymers of formaldehyde. The ones that are important in our foods fall into two groups, the simple sugars and the double sugars.

There are a number of kinds of simple sugars. All of them have the same composition; the formula is $C_0H_{12}O_6$. The difference between them is in the way the atoms are arranged in the molecules. The commonest of the simple sugars is glucose. Another common one is fructose (fruit sugar or grape sugar). The graphic formulas of these two sugars are given below. Note that each molecule contains an oxygen atom joined to a carbon with a double bond. Note also that these are attached in different places in the glucose and fructose molecules.



FORMULA FOR GLUCOSE



FORMULA FOR FRUCTOSE

The double sugars have the formula $C_{12}H_{22}O_{11}$. They have twelve carbon atoms in the molecule. The most familiar double sugar is sucrose, or common table sugar, which is obtained from sugar cane and beets. Lactose or milk sugar, which is in milk,

and maltose or malt sugar, which is obtained by the malting of grain, are other double sugars.

Double sugars are formed by combining two molecules of simple sugar and dropping a molecule of water in the process.

$$2 C_6 H_{12} O_6 \longrightarrow C_{12} H_{22} O_{11} + H_2 O$$

When a double sugar is digested the process indicated above is reversed. A molecule of water is taken up and the double sugar molecule is broken into two molecules of simple sugar. Sucrose yields a molecule of glucose and one of fructose. Maltose splits into two molecules of glucose. Lactose yields one molecule of glucose and another simple sugar called galactose. Double sugars can be split into simple ones by boiling with acids as well as by digestive enzymes.

The starches. Starches are polymers of sugars. When they are broken up they yield malt sugar. The starch molecule is large, but its exact size is unknown. The general formula is written thus: $(C_0H_{10}O_5)_n$, with n representing the number of simple sugar molecules in the starch molecule. It is thought that there are about thirty sugar molecules linked together in a molecule of starch. You will note from the formula in the parenthesis that a molecule of water is dropped from each sugar molecule when starch is formed.

Plants store food as starch, but each kind of plant builds its own kind of starch. With a microscope you can easily distinguish between the starch grains of potato, corn, wheat, and oats. As a food, however, all starches have equal value. They are built from sugar and, when digested, all break down into sugar again.

Oils. Many plants instead of storing their carbohydrate as starch convert a part of it into oil (liquid fat). Then the oil is stored in the plant cells, especially in the cells of the seeds. Corn oil, cottonseed oil, coconut oil, peanut oil, soybean oil, linseed oil, and castor oil are all familiar vegetable oils. Most of these oils come from seeds where they have been stored as food for the baby plants. Like starches and sugars, oils contain carbon, hydrogen, and oxygen, but the proportion of oxygen is

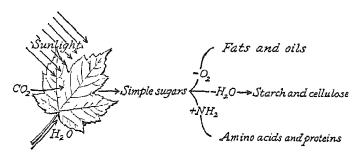


Diagram illustrating some of the building processes that go on within a green plant. Sugar is formed in photosynthesis. Then by transformations of the sugar molecules and by additions to them and subtractions from them the almost countless other compounds found in plants are produced.

less in the oils and their energy values are much higher than the energy values of the carbohydrates.

Organic acids. Plants build another set of compounds, the organic acids. These are what make fruits and vegetables sour. Malic (mål'ĭk) acid is found in apples, citric acid in oranges and lemons, tartaric acid in grapes, and oxalic acid in tomatoes and rhubarb. Bacteria convert cider into vinegar by forming acetic (a-sē'tĭk) acid from the alcohol of the cider. Milk is soured by bacteria that ferment the sugar in it and in so doing make lactic acid. There are many different organic acids and all of them

have in their molecules at least one -C-O-H group. Acetic acid

H O is H-C-C-O-H. Vitamin PP, which prevents pellagra (pe-lā'gra), H

has been proved to be an organic acid which is present in many foods.

Amino acids. The radical NH_2 is called the *amine radical* ($\mbox{am}'\mbox{in}$) or the *amino radical* (a-me'no). Its graphic formula is

-N-H. When this is substituted for a hydrogen atom in an organic acid, an amino acid is formed. Copy the graphic formula for acetic acid given above. Then erase an H attached to the first

C and substitute for it the amino radical. You now have the formula for glycin, one of the simplest amino acids. Its simple

formula is
$$C_2H_5O_2N$$
. Its graphic formula is H - C - C - O - H .

Twenty-two different amino acids are known and some of them have much larger molecules than glycin. In addition to the four elements in glycin some of the amino acids contain also atoms of sulfur. In the construction of proteins from amino acids, phosphorus, calcium, iron, magnesium, or other elements may be built in. Amino acids are manufactured by green plants. The process can take place in the dark and in colorless tissue as well as in cells that contain chlorophyll. Fungi and some of the protozoa can build all the amino acids that they require. The higher animals can make only thirteen of the twenty-two different kinds they need, and must get the others from their food. Some of the amino acids are chain compounds and some are ring compounds, and in general it is the long chain and ring amino acids that the higher animals cannot build.

Proteins. Proteins are built from amino acids and there are many kinds of them. The different proteins may differ in the kinds of amino acids of which they are composed and also in having the various amino acids they do contain in different proportions. The molecules of some proteins contain thousands of atoms. If we except the filterable viruses and living protoplasm, they are the most complex chemical substances that are known. Proteins are storage forms of amino acids, just as starch is a storage form of sugar. Animals, in digestion, break proteins apart into amino acids and then within their bodies build them together into proteins of their own particular kinds.

Other compounds built by plants. Plants build hundreds of other compounds — resins, gums, waxes, wood, cork, poisons, substances that give to the plants their odors and tastes. Each plant species builds compounds peculiar to itself. It would

not be a species if its chemistry were not different from that of other plant kinds. The growth, the form, the size, and all the other characteristics of a plant are the result of the chemical processes that go on within its cells.

Some of the many substances that we find in plants in only small amounts are useful to the plant. Others seem to be useless by-products which the plant stores because it has no way of getting rid of them. The perfumes and pigments of flowers that attract insects and the poisons and bitter-tasting substances that protect leaves and seeds from animals are examples of useful substances. The milky juices of milkweeds and the rubber tree, the turpentine of the pine, and the red pigments of autumn leaves are examples of products that seem to be useless to the plants that produce them. Among the many substances that green plants build in small amounts are enzymes, hormones, and vitamins. All of these are necessary for the plant's own life and the plant vitamins are necessary for animal life as well. Cellulose, the principal material in the cell walls of plants, is a complex carbohydrate polymer very similar in its formula to starch. By treatment with acids it can be broken down into sugar as starch is. In wood, cellulose is mixed with lignin, which is not a carbohydrate but is chemically related to the carbohydrate group.

Foods are substances that can be taken into the cells, that supply energy or building material or both energy and building material to the cells, and that in considerable amounts are not harmful to the cells. Most foods must be digested before they can be used, and because organisms differ in the enzymes they have they do not all use the same foods. We cannot, for example, digest cellulose, but some small animals and many fungi and bacteria have cellulose-digesting enzymes and hence these organisms find in cellulose a food supply. The bookworm can feed on paper, the termite on wood (page 214), and the clothes moth on woolen clothes, because each of these organisms is equipped to digest the particular substance it eats.

PROBLEM THREE

How Do Living Things Use Foods?

Plants and animals use foods in the same ways. They use them to build and repair their tissues. They use them to supply themselves with energy. They carry on respiration in their cells, which means that they oxidize the foods and secure the energy that is stored in the food molecules. The three great classes of foods are the carbohydrates (starches and sugars), proteins, and fats.

Necessity for digestion of food. Most of the food that accumulates as a surplus food supply in plants is in storage form. Most of the food that we eat is in storage form. It has been built up into large insoluble molecules and before it can be transported through the plant or animal body or used by the cells it must first be digested, or broken down into smaller molecules that will go into solution. In digestion starch is converted into simple sugars. The proteins are split into amino acids. Fats are split into glycerins and fatty acids. Digestion is the reverse of synthesis. In digestion food molecules are split up into smaller molecules.

Digestive enzymes. These high-powered chemicals, like the vitamins and hormones, are present in unbelievably small amounts; but the enzymes split the food molecules without themselves being altered and therefore they can keep on and on until their work is done. The enzymes are compounds manufactured by the cells. The building of them is a part of the wonderful activity that protoplasm carries on to provide itself with a food supply. Not only the digestion of food but the oxidation of the food within the cells is carried on by these "organic catalysts" (page 121).

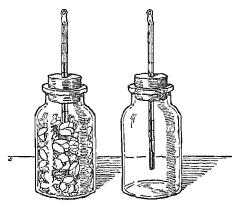
Both plants and animals have enzymes. The saliva contains an enzyme, ptyalin (tī'a-lĭn), that digests starch, and the gastric juice an enzyme, pepsin, that digests protein. An important enzyme in plants is diastase (dī'a-stās), which converts starch to sugar. Plants also have other enzymes for digesting proteins and for breaking down fats.

Measuring energy content of foods. An organism may use the energy in foods in building processes or in the production of warmth. An animal may use it in muscular work. However it is used, it is convenient to measure the energy content of different foods in the same unit, and in this measurement the Calorie, or heat unit, is used. A Calorie (spelled with a capital C) is the amount of heat required to raise the temperature of 1 liter (1 kilogram) of water 1 degree centigrade.

By experiment it has been proved that when foods are oxidized within the body of an organism they yield exactly the same amounts of energy as they do when burned outside of it. A gram

of dry carbohydrate or protein yields 4.1 Calories. A gram of fat produces 9.3 Calories. As will be noted, fats are high in energy content. Fat meat and butter are good winter foods because they yield much heat.

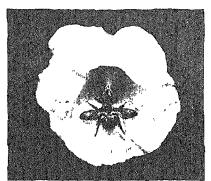
Uses of carbohy-drates and fats. The carbohydrates and fats are the fuel foods. They are valuable not for building material, but for the energy they supply. In both plants and animals,



Experiment showing that plants give off heat. One bottle is filled with flower buds or germinating beans or peas. The control bottle is left empty. The experiment works better if the bottles are wrapped in cloth or paper to retain the heat.

fats and carbohydrates are oxidized to carbon dioxide and water. In both plants and animals, energy is released in the oxidative process. In an animal the energy not used in chemical processes

¹ The gram calorie (spelled with a small c) is the unit used in heat measurements in physics and chemistry. It is the amount of heat required to raise the temperature of 1 cubic centimeter (1 gram) of water 1 degree centigrade. It is 1000 of the kilogram Calorie described above.



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Bureau of Entomology and Plant Quarantine

The little people of the fields and woods discovered long before man that plants give off heat. A bee caught away from home by darkness often seeks the warmth within a flower.

is given off as heat or, in an active animal, a considerable part of it may be used in muscular work. In a plant it is used in building or is lost as heat.

You can prove that plants give off heat by the experiment indicated on the preceding page. A thermometer placed inside the sheath about the flower head of a jack-in-the-pulpit or a calla lily will show a temperature higher than the air.

A bee caught away from home by darkness often seeks the warmth within a partly open hollyhock flower.

Uses of proteins. The proteins also give energy when they are oxidized, 1 gram of protein yielding 4.1 Calories — the same amount as a gram of carbohydrate. The chief use of the proteins, however, is to furnish building material to the cells. Protoplasm is a protein substance and proteins are necessary to life because they supply the materials from which protoplasm is built and repaired.

In their building processes the cells do not use whole protein molecules. They use the amino acids into which the protein molecules are split in digestion. The cells pick these protein fragments out of the blood stream and combine them into proteins of their own kinds. There are twenty-two kinds of amino acids known, and different proteins, when they are digested, yield them in different proportions. Some proteins (as gelatin) do not furnish certain amino acids that are necessary for animal life and these are called *inadequate proteins*.

Other proteins furnish all the kinds required for maintenance of an animal but fail to furnish some that are necessary for growth. If a young animal is fed only on the maintenance ones it is healthy but fails to grow. In general, animal proteins like those of meats, eggs, and milk furnish more complete assortments of the necessary amino acids than vegetable proteins. Some vegetable proteins, however, are of much higher quality than others. Twelve of the twenty-two amino acids are required for growth. Proteins that contain all the amino acids necessary for the maintenance and growth of one of the higher animals are called adequate proteins. The casein of milk, from the point of view of the amino acids furnished, is the best protein known.

In plants, of course, there is no question of inadequate proteins, for a plant makes its own proteins. Given the needed mineral salts, it can transform other food substances into the amino acids that it requires.

Minerals necessary to life. An animal must have a number of minerals in small amounts for building purposes. Calcium phosphate is required for building the bones and teeth, and iron is needed for the construction of the hemoglobin of the red blood corpuscles. Iodin is necessary for the building of the secretion of the thyroid gland (page 506).

Furthermore, minerals must be in solution in the plasma of the blood and in the lymph in which the cells are bathed. Of the minerals in these fluids, common salt is present in the largest amount. We habitually add salt to our food to keep up the body supply. Flesh-eating wild animals get salt from the bodies and tissues of their victims, but herbivorous animals must often travel long distances to reach salt licks. Potassium, calcium, and a number of other mineral elements also are present in the blood and lymph. The truth is, the cells of higher animals are still salt-water organisms; the mineral composition of the lymph is almost the same as that of sea water.

The mineral requirements of plants have already been discussed (page 553). The nitrogen, phosphorus, sulfur, and other elements that animals get in their proteins the plants must obtain from the soil.

Food reserves. Both plants and animals can store foods for future use. Under a summer sun plants often manufacture

more food than is required for their immediate needs and this extra food is changed into storage forms and put away. A potato stuffs the cells of its tubers with starch. A lily changes its sugar into oils which form droplets in the cytoplasm of the cells. Sugars, starches, proteins, and oils are stored in the seeds of plants to be used by the coming generation.

Animals too provide in their bodies a food reserve. In the human body carbohydrate is stored in the liver and in the muscles in the form of a starch-like compound called glycogen (glī/ko-jĕn). The body fat is a great supply of energy-yielding food that can be drawn on in time of need. In the blood there is a protein store, and the muscles form a protein reserve, a large part of which can if necessary be used for the nourishment of the nervous system and the heart and other vital organs. The transformation of foods into storage forms and the breaking of them up again into usable form are chemical processes that go on constantly in all living things.

The term *metabolism* is used to designate the chemical changes that go on within the cells. It is sometimes used in a narrow sense to mean only the chemical processes concerned in the building up and breaking down of protoplasm. In its usual and wider meaning the term includes the processes connected with food storage, the oxidation of energy-yielding foods, the processes of growth and protoplasm repair, and the many other chemical processes that living protoplasm carries on. By the metabolism of an organism we mean all the chemical changes that go on within its cells.

PROBLEM FOUR

What Is the Rôle of the Vitamins in Animal Nutrition?

Perhaps the greatest of the hygienic triumphs of the present century was the discovery of vitamins. It was learned that a person might have an abundance of "good, nourishing food" and yet become ill or die from malnutrition. It was found that persons and animals with certain illnesses could be cured as if by magic when fed almost microscopic amounts of substances extracted from foods. For a long time these substances were known only by their effects. Now a number of them have been isolated and their chemistry is known. They belong to various groups of chemical compounds, but they are much simpler in structure than the proteins. Nearly all known vitamins are products of plant chemistry. With the exception of vitamin D, the vitamins that are in animal tissues and in milk and eggs have been collected by animals from plants.

Names of vitamins. Vitamins are called vitamin A, B, C, D, and so forth, and evidence of the existence of enough of them has been discovered to exhaust the letters of the alphabet. Eight of them are known to be essential to human nutrition. Others are substances that promote the growth of bacteria, yeasts, or other organisms. Some may be necessary for the maintenance of health in one animal and not in another. As the chemistry of the vitamins becomes known there is a tendency to call them by definite names rather than to designate them by letters. For example, vitamin B is called thiamin (thī-ām'īn), vitamin C ascorbic acid, and vitamin PP nicotinic acid.

Each vitamin seems to affect some particular chemical process or processes and without it a derangement of the metabolism appears. Each one is a definite chemical compound and each one produces a definite chemical effect. Without the vitamins the normal processes of the body are not carried on. It is difficult to make general statements that will apply to all the vitamins;

so we shall discuss individually a few of the better-known ones and their effects in the higher animals.

Vitamin A. In the petals of yellow flowers and in many plant tissues there is a yellow pigment. It is abundant in carrots and is called carotene (kăr'o-tēn). It is present in grass and gives the yellow color to cream, butter, and yolk of egg. Leaves in general contain it, and yellow vegetables and yellow corn get their color in large part from it.

This yellow pigment is provitamin A. It is not itself the vitamin but is the substance from which the liver of an animal makes vitamin A. It is clear that having carotene in the diet is as good as having the vitamin itself. In cod-liver oil, in halibut-liver oil, and in sardine oil there is a rich supply of the vitamin already prepared. Very fortunately the animal body can store sufficient supplies of vitamin A to meet its needs for a considerable time.

When a rat or a guinea pig is fed a diet lacking in vitamin A its appetite fails, its hair becomes dry and rough, and its growth is slow. The mucous membranes become dry and hard. The eyes also show the lack, and there is a recognized disease of the eye ("night blindness") that occurs among persons who live on diets very low in this vitamin. The lining of the sinuses, respiratory passages, and the alimentary canal are affected, and also the kidneys. All these parts are likely to become infected with bacteria and many physicians consider an abundant supply of vitamin A important as a protection against infections of the tonsils, sinuses, kidneys, and other parts.

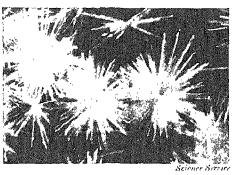
Vitamin B. Vitamin B is the antineuritic vitamin, the one that protects the nerve tissue against degeneration and prevents the disease called beriberi. Besides having a beneficial effect on the nervous system, this vitamin accelerates the metabolism and increases the rate of growth. It also gives tone to the involuntary

 $^{^1}$ What was once called vitamin B has now been divided into a whole family of vitamins. Sometimes the fractions are called B_1 , B_2 , B_3 , and so on; sometimes they are designated by other names. The name vitamin B is now usually reserved for the antineuritic vitamin whose effects are described above. Its chemical name is thiamin.

muscles and without it the stomach and the intestines tend to lie inert and the appetite fails.

Vitamin B is especially abundant in the outer layer of grains. Whole wheat and brown rice (unhulled rice) supply it, but white

wheat flour and white rice that has had the bran polished off are very low in it. Brewer's yeast is an especially rich source of this vitamin and most fruits and vegetables contain it in moderate amounts. Milk and eggs have it, but their richness depends on the diet of the cows and hens. Meats are only moderately rich in vita-



Crystals of vitamin B. Three millionths of an ounce of this substance is sufficient for the daily need of the human body, but if this supply fails life cannot go on.

min B. For persons with poor appetite, constipation, and general inactivity of the digestive organs, physicians sometimes recommend foods especially rich in vitamin B or prescribe one of the preparations that are made to supply it.

Vitamin C. The lack of vitamin C causes scurvy. This disease was formerly very common among sailors on long voyages and among others who lacked fresh food. The victims first showed soft gums that bled easily; then their lips and the tissues of other parts became swelled, and death might be the ultimate result. Besides causing scurvy, the lack of vitamin C causes defective teeth to be formed in a young animal and a low supply of it may explain a general feeling of lassitude and of not being well in both children and adults. Experiments on animals indicate that it requires about four times as much vitamin C to build sound teeth as it requires to prevent fully developed cases of scurvy.

Vitamin C is supplied especially by fresh fruits and fresh vegetables. Like vitamin B it is soluble in water and if the water in

which vegetables are cooked is thrown away much of the vitamin may be lost. A part of it is destroyed by oxidation in cooking and canning. Mainly because of their acidity, it is especially well preserved in canned tomatoes and grapefruit and in tomato, orange, and grapefruit juice. The fact that only a limited amount of vitamin C is stored in the body makes it important that fresh fruits or vegetables be included in the diet all through the year. It is recommended that a baby be given orange or tomato juice at one or two months of age and purée from strained vegetables at six months.

Vitamin D. Vitamin D is concerned with the calcium and phosphorus metabolism of the body, and children, who must build bones and teeth, suffer especially from a lack of it. This vitamin is built in the animal body by ultraviolet radiation falling on the skin; therefore in summer most persons have a sufficient supply of it. In winter, however, in cities at the latitude of New York and Chicago, there is a period of about three months when little of the ultraviolet of the sunshine comes through to us, and then our vitamin D supply is likely to run low. Formerly the great majority of the children in our Northern cities suffered from rickets during the winter months. Since ordinary window glass cuts off the ultraviolet rays, light that has passed through it will not build vitamin D.

The only foods in which vitamin D is really abundant are liver and the yolk of egg. It is produced in summer to a slight extent by the sunshine falling on vegetables and there is a considerable amount of it in the milk of cows that have been out in the sunshine and have pastured on summer grass. Vitamin D being especially abundant in oil from the livers of fishes, cod-liver oil and halibut-liver oil are used to supply it. On most poultry farms hens are given cod-liver oil during the winter months, with the result that eggs from hens fed in this way are rich in vitamin D.

Vitamins E and F. Vitamin E is called the fertility or antisterility vitamin because without it animals have no young. In the absence of the vitamin the fertilized egg dies instead of developing, even when the parent animal seems to be in health.

Vitamin E is found in lean meats and animal fats and in green leaves and embryos of seeds. Wheat-germ oil is an especially rich source of it. It can be stored in the body for long periods of time.

Vitamin F is one of several little-studied vitamins that along with vitamins B and PP can be dissolved out of the outer layers of grains by water. Vitamin F is necessary for the growth of pigeons, but little else is known of it. The pure compound has not been isolated and its chemical structure is still unknown.

Vitamin G. Vitamin G is abundant in milk, and whey is especially valuable for its high content of it. Riboflavin, which is the chemical name for vitamin G, is present in every living cell. It is a building block used in the construction of a very important enzyme which carries on the oxidation of food materials. Riboflavin is so generally present in the foods we eat that animals and human beings very seldom suffer for lack of it. Rats on diets without this vitamin develop cataracts in their eyes. Recently it has been reported that perleche, a condition in people in which the mouth and lips become cracked and sore, is due to an insufficient supply of vitamin G.

Vitamin PP. Like thiamin and riboflavin, vitamin PP plays an essential rôle in oxidation within the cells. Eggs are more than ordinarily rich in it and lean meat contains it. Tomatoes, collards, and turnip greens also supply this vitamin, while white wheat flour, corn meal, sweet potatoes, molasses, and fat salt pork lack it. Brewer's yeast is rich in it and is used when there is need for an unusual supply. Vitamin PP is found also in the whole grains, such as brown rice.

The lack of this vitamin is the cause — or one of the causes — of pellagra, a disease that at times is a serious problem in our Southern states. The disease is not found among those who have a diet that contains milk, eggs, meat, and fresh vegetables. Yeast has been distributed by boards of health to prevent it. Black tongue in dogs is similar to pellagra in human beings and is believed to be caused by lack of vitamin PP. Chemically this vitamin is nicotinic acid, a chemical that has long been known.

Importance of abundant vitamin supply. Guinea pigs were divided into four groups, and the first group was given enough nicotinic acid to keep them growing and from becoming ill. Then to the second, third, and fourth groups two, three, and four times as much nicotinic acid was given as the first group had. With each increase in the amount of the vitamin there was an increase in weight and an improvement in the condition of the animals. Enough of the vitamin to keep them from becoming ill was not enough to keep them in the highest possible health.

In the same way it has been shown that unusually large amounts of vitamin B improve the condition of animals supposed already to be in health; that amounts of vitamin C up to the quantity in a pint of orange juice, taken daily, progressively increase the strength of the capillary walls in children from 8 to 15 years of age; and that rubbing with oil that is rich in vitamin D improves the health of the skin. Scientific laboratory experiments and scientific medical studies both indicate that a higher level of well-being for a considerable percentage of our population would result from an increased vitamin supply.

The foregoing discussion of the vitamins might give the impression that each one of them does just one particular thing and nothing else. This is not always the case. Vitamins A, C, and D all seem to be required for building and keeping sound teeth. Vitamin C is needed for sound bones as well as for the prevention of scurvy. The lack of B causes not only nerve trouble but also several other difficulties. The full effects of the different vitamins are not yet understood. Besides the vitamins we have discussed there are several others that are known to be concerned in human metabolism. One of them — vitamin K — is essential for the formation of the substance that causes the clotting of the blood.

It is a curious circumstance that a living thing should require minute amounts of many different substances to regulate its chemical processes, but that it does require these substances is a fact. Plants as well as animals must have vitamins. Without them the body processes are not carried on in a normal way.

PROBLEM FIVE

What Principles and Rules Can Be Used for Guidance in the Selection of a Human Diet?

About forty different substances are known to be necessary in the nutrition of a higher animal. These include twelve amino acids, thirteen vitamins, a group of minerals, sugar, and at least one particular fatty acid (linoleic acid). There must be a sufficient supply of all these substances, and between the amounts of some of them a proper balance must be maintained. Obviously the making up of diets from the various foodstuffs that are available — keeping in mind also the factors of cost and convenience of preparation — is in itself an important application of science. In our present study we can give attention to only a few facts that may in a general way be helpful in the selection of food.

Dangers of restricted diet. Any restricted diet in unskilled hands is dangerous. We depend on picking up by chance the vitamins, minerals, and amino acids we need from the diet, and when we limit the foods that we eat to only a few kinds there is danger that some needed substance will not be supplied.

It is wise to include all kinds of foodstuffs in the diet and it is wise to be particularly careful to include a liberal supply of milk, eggs, and fresh vegetables. These are high in minerals and vitamins; they have been called the *protective foods*. In hospitals, patients who are put on reducing diets are given in tablets or capsules an artificial supply of the vitamins and minerals that the restricted diet may fail to supply.

Keeping the body at proper weight. If the ductless glands of the body are working properly and the body is in health, keeping the correct weight is a matter of eating the right amount of food. If we eat more than is required the surplus is stored and weight increases. If less is eaten than is needed the body oxidizes its own substance and falls below normal weight. The body keeps its own account of income and outgo and the scales will give the balance at any time. If the weight is too low the income

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should be increased. If it is too high the income should be lessened and the body allowed to oxidize its own fat.

However, there are cases of overweight in which fat is stored because of lack of hormones or in which the tissues are heavy with water. Before trying to reduce weight a person should consult a physician to make sure that the difficulty is a simple one caused merely by too great an intake of food.

Principles of a reducing diet. The principles of a reducing diet are very simple. The full intake of proteins, vitamins, and minerals is kept up. The intake of the fuel foods (sugars, starches, fats) is reduced. The purpose is to make the body use its own fat for fuel. A heavy person has in his body no surplus of proteins, vitamins, and minerals; so the usual supply of these should be kept up. The excess weight is caused solely by an accumulation of fat and the only possible way of getting rid of this is to oxidize it. To reduce its weight, the body must be compelled to use for fuel its own fat.

Lean meat, fish, egg white, skim milk, buttermilk, and cottage cheese furnish protein in relatively pure form. These foods should be taken freely, for in order to maintain a feeling of well-being it is highly important that the protein intake be kept at the full amount. Large amounts of leafy vegetables and fruits help to keep up the vitamin and mineral supply. The bulk of these foods in the stomach also helps to prevent hunger. It is possible to supply some of the vitamins artificially and when this is done it is easier to guard against dietary deficiencies.

Fats are the highest of all foods in energy and the ones that add most to the body's weight. They are therefore held to a low point in a reducing diet. Vegetable oils and pork fat furnish no vitamins and they should be omitted entirely. Any fat that is taken should be high in vitamins. Butter, egg yolk, and the fat in milk are of this kind. The carbohydrates that are taken should be secured from vegetables and fruits that will furnish vitamins and minerals also. Sugar and starch carry no vitamins or minerals and should be cut to low amounts or omitted. Spaghetti, macaroni, white bread, syrup, cake, and fats are the

wrong foods for one who is inclined to be overweight. We must keep down the energy intake (Calories) and keep up the supply of the materials for the building and life processes.

A simple reducing diet. The following is given as an example of a diet that reduces the Calorie intake and yet maintains the supply of necessary material constituents:

Break fast:

Juice of 1 orange added to whipped white of 1 egg Fish or meat, 2 ounces Bread, ½ thin slice (½ ounce) Coffee with no cream or sugar

Lunch or dinner:

Low-Calorie vegetables, 4 medium-sized helpings Meat, cooked, lean, 3 ounces (4 x 3 x ½ inch) Grapefruit, 1/2 Bread, ½ thin slice (½ ounce)

Supper:

Low-Calorie vegetables, 4 medium-sized helpings Milk, 1 glassful Cottage cheese, 2 ounces (2 heaping tablespoonfuls) Bread, 1 thin slice (1 ounce)

LIST OF LOW-CALORIE VEGETABLES

(May be used fresh or canned)

Dadiahaa

Dandelien

Artichokes	Dandelion	Radishes
Asparagus	Egg plant	Rhubarb
Beet greens	Endive	Sauerkraut
Broccoli	Kale	Sorrel
Brussels sprouts	Leeks	Spinach
Cabbage	Lettuce	String beans (very young)
Cauliflower	Marrow	Tomatoes
Celery	Mushrooms	Turnip greens
Collards	Okra	Water cress
Cucumbers	Pumpkins	

Other low-Calorie vegetables, but not so low as those listed above, are: beets, carrots, green peas (very young), kohlrabi, onions, parsnips, string beans, squash, and turnips. One helping of these is about equal in Calories to two helpings of the first group. 636 NUTRITION

Fruits (except grapefruit) are higher in Calories than the lowest group of vegetables. Blackberries, lemons, muskmelons, oranges, peaches, pineapples, raspberries, strawberries, and watermelons are on an average about equal in carbohydrates to the vegetables in the second group. Apples, bananas, and pears among fruits, and corn and potatoes among vegetables, are in a third richer group.

Usually it is best not to try to reduce too rapidly; 2 to 3 pounds a week are enough to lose (1 pound if this rate of loss can be maintained). Some persons seem to do best by getting into the diet gradually. If there is hunger between meals a drink of water or a cup of tea or clear bouillon may help appease it. Apples are particularly good for relieving hunger and bulky foods like raw cabbage may be helpful. Plenty of liquid may be taken. It has been shown that going without water does not increase the amount of food oxidized.

A common mistake made in attempting to lose weight is to cut down not only the body's fuel supply but also the proteins and other substances that are necessary for its life. Without these substances there is a feeling of weakness and hunger. Often the face looks drawn. The reducing process is a failure because the diet proves inadequate to support health. The error is made of reducing not only the intake of fuel foods but of the building foods, vitamins, and minerals also. In any diet a full supply of these is necessary.

Diet for persons underweight. A person may be underweight either because he eats too little food or because he is too active and oxidizes the food too rapidly. To build up the weight, the rules given for reducing it should be reversed. A diet high in energy should be selected and as much physical rest as is possible should be taken. Fatty foods and foods rich in starch are especially valuable for increasing the weight. Eating between meals increases the daily energy intake. Thinness is likely to be accompanied by a sinking of the stomach in the abdominal cavity. There are many young persons whose health is improved by an increase in body weight.

Danger of dietary deficiencies. Our great dietary danger is that the foods will not supply adequate amounts of some of the many substances that are required for the infinitely complex chemical processes of the cells. In choosing a diet the following points should be held in mind.

Fats are necessary in the diet. They are valuable not only for themselves but also because some of the vitamins are dissolved in them. Vitamins A, D, and E do not go into solution in water but are soluble in fats. They are therefore found only in tissues where fat is present. In milk, vitamins A and D are in solution in the fat droplets (cream).

Milk does not contain iron. When a baby is born its liver contains enough of this mineral to supply its needs for some months, and when this store is exhausted it needs, in addition to milk, food that will furnish iron. The needed iron is usually given in yolk of egg or soft leaf vegetables.

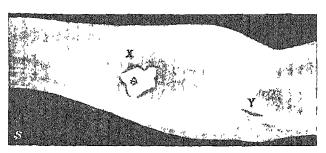
Salt is lost from the body in the perspiration and through the kidneys. Sometimes when men perspire profusely, as in heated mines or boiler rooms of ships, the loss of salt is so great that illness results. It has been found that this sickness can be prevented by adding salt to the drinking water. Men at work in a hot desert sometimes drink as much as a quart of salt water an hour.

Another mineral that is added to the diet in goiter regions is iodin, and in special cases physicians may prescribe calcium, phosphorus, or iron.

Sensitivity to foods. An occasional person is sensitive to a certain food or foods. The food may give him hives, may cause headaches, or may affect him in some other way. Inhaling pollen or organic dusts (as from hair, feathers, face powders, house dust) may have similar effects. Many persons have hay fever from grass or ragweed pollen, and many substances may cause asthma when inhaled.

This condition of sensitivity is called *allergy*. The person who is sensitive is said to be *allergic*. The difficulty in cases of allergy seems to be that for some reason the chemical reactions do not

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Result of a skin test on an asthma patient, with horsehair protein. At X a scratch in the skin was made and the protein rubbed in the slight wound. A control scratch was made at Y, but no protein was applied.

follow the normal course. Usually, but not always, the allergy is caused by a protein. A person may be sensitive to a single food or to many different foods. Those allergic to many substances may be at all times in a low state of general health because of their abnormal reactions.

An allergic person should try to find out what foods are affecting him and if possible omit them from his diet. Skin tests often are a great help in locating the offending substances. A physician can give these tests and in some cases can remove the allergy by vaccination. The cause or causes of allergy are not known. The physiological processes connected with the overcoming of it seem to be similar to those active in the building of immunity.

Persons who continue in health and at a reasonable weight need not worry about their diet. The fact that they remain in health shows that their food is supplying their body needs. If, however, a person is not well and vigorous he should consider the possibility that the trouble is in his nutrition. Without the right fuel the human motor will not perform satisfactorily, and its fuel requirements are very complicated. A diet may be 99.99 per cent correct and yet be inadequate to sustain life.

PROBLEM SIX

What Effects Have Alcohol and Other Habit-Forming Substances on the Metabolism and Health?

Foods, vitamins, minerals, and oxygen are taken into the cells. In the living protoplasm they go into a swirl of chemical activity of unknown complexity to us. Many persons by the use of alcohol, tobacco, coffee, tea, or certain drugs concentrated from plants introduce into this dynamic situation foreign substances that influence the cell processes. Our present brief study deals with these foreign materials and their effects.

Commonly used habit-forming substances. The habit-forming substances most commonly used in our country are alcohol made by the fermentation of grains and fruit juices; nicotine found in the leaves of the tobacco plant; morphine and heroin which are derivatives of opium; cocaine from the leaves of a tropical shrub called the coca plant; marijuana from Indian hemp; and the caffein and thein of coffee and tea.

All these substances are organic compounds. All of them have marked effects on the protoplasm so that a comparatively small amount will produce even death. All of them affect particularly the nervous system. Why these compounds should be habit-forming while many other compounds are not, no one knows. We know their effects, but not how they produce them or why.

Changed cell metabolism. The continued use of habitforming substances seems to change the normal processes of the cell and to set up new processes for the carrying out of which these substances are necessary. That the reactions which go on within the cells can be changed, we know from our experiences and studies in immunity. If diphtheria toxin is injected into the blood, antitoxin is produced. Five, ten, or twenty years later the cells may still be producing antitoxin. One attack of smallpox or measles usually gives immunity for a lifetime. The metabolism is permanently changed by the attack so that the 640 NUTRITION

cells continue to produce immune bodies. In the same way it would seem that habit-forming substances change the original processes of the cells.

It should be noted too that different persons are affected differently by these substances. They take hold on some more quickly and strongly than on others. In considering and dealing with the whole alcohol and drug problem, individual susceptibility should be taken into account.

Alcohol. Because of a combination of wide use and serious effects following its use, alcohol is in our country by far the most important of the habit-forming substances. Its chief immediate effect is on the nerve tissues. It is a narcotic — a depressor of the action of the nervous system. After alcohol is taken the heartbeat is quickened and the person may seem more lively, but this seeming stimulation is a result of taking off the controls exercised by the central nervous system. So severe, indeed, are the narcotic effects of alcohol that a tumblerful (one-half pint) of pure alcohol is fatal to a person not accustomed to it — it sends him into a stupor from which he does not awake.

Of the long-time effects of the habitual use of alcohol on the different organs of the body we cannot treat here, but the sum of its effects on health and body well-being can be quickly presented through the use of life insurance statistics. The accom-

		a		_	
EFFECTS O	יזור	ALCOHOL	on	DEATH.	RATES

Group	AMOUNT OF ALCOHOL TAKEN	Death Rate	EXCESS PER- CENTAGE OF DEATHS
Abstainers	Neveruse alcohol in any form.	100%	
Moderate drinkers	Use alcohol occasionally. Sometimes become a little tipsy.	109%	9%
Excessive drinkers	Occasionally use alcohol in excess. Become drunk a few times a year.	195%	95%

panying table shows the death rates among abstainers and users of alcohol according to the figures of one company. In the computations allowances for any differences in age in the various groups were made so that the figures are comparable.

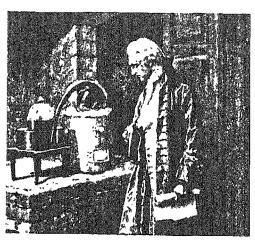
Alcohol as a food. Is alcohol a food? The answer depends on the definition of food. Alcohol is oxidized in the body; it yields energy to the body. Some heavy and constant drinkers get a very considerable part of their energy from alcohol and eat little carbohydrate. If we define a food as a substance that yields energy or building material to the body, then alcohol is a food and according to this definition quinine, strychnine, and opium also are foods, for they are oxidized in the cells. If, however, we think of a food as a substance that yields energy or building material to the body and at the same time does not injure it, when taken in large amounts, then opium is not a food and by this definition alcohol is not a food. It differs in its effects from such foods as bread, milk, and meat. It is taken not for its food value but for its drug effects.

In small amounts might alcohol be harmless or beneficial to the body? Theoretically this could be true. We have no evidence that it is true and we cannot prove that it is not true. We cannot trace the effects of a few drops of alcohol in the body. We cannot be sure of the results of its occasional use in small quantities as we can when it is used in large amounts. Our measurements are not yet fine enough to determine the effects of alcohol when used in very small amounts.

The purpose of this problem has been to call your attention to these habit-forming substances as something apart from the ordinary materials we meet in the world. It is said by those who have knowledge of the matter that many young persons get started on their use through mere curiosity and thoughtless experimenting. A scientific consideration of your relation to them will take into account the dangers inherent in them. They snap as a trap and take their victims by surprise. They are not to be treated as ordinary substances are.

AN ORGANISM A CHEMICAL MECHANISM

The American Indians, when first shown a watch, thought that it was alive. Now we tend to think of a living organism as a machine. One hundred and fifty years ago, the French scientist



Antoine Laurent Lavoisier (1743-1794). He proved the true nature of oxidation and respiration, demonstrated the indestructibility of matter, and introduced the scientific method in the study of chemistry and physiology. When he was beheaded the philosopher Lagrange exclaimed, "A moment only was required for the fall of this head, and one hundred years may not be enough to produce another like it."

Lavoisier (la'vwa'zyā') wrote "Life is a chemical process." Modern knowledge confirms the views of this illustrious scientist who first conceived of a living organism as a chemical machine.

Lavoisier was a scientific genius of the first rank. He was the first to find the true explanation of oxidation — that it is the uniting of oxygen with another substance. He proved that the human body uses oxygen and gives off carbon dioxide and suggested that it gets its energy from the oxidation of food within it. For the first time he intro-

duced exact weighing and measuring methods in scientific experimentation. Chemists regard him as the Father of Modern Chemistry and physiologists look on him as the Founder of Modern Physiology. He was beheaded during the French Revolution, and when a petition was presented in his behalf, the President of the Tribunal is reported to have replied, "The Republic has no need of savants."

UNIT COMPREHENSION TEST

- A. Define: organic chemistry; valence bonds; radical. Write the formula for methane, ethane, and propane. Illustrate how new kinds of molecules are formed by substitution. How is an alcohol formed? Describe the molecule of a fatty acid. How is a fat formed? What are the two main plans for placing the carbon atoms in the molecules of organic substances? What are some important characteristics of organic compounds?
- B. Explain what happens in photosynthesis. Define: polymerization; simple sugar; double sugar. Write the equation for the formation of a double sugar. How are starches formed? Into what are the carbohydrates often transformed for storage? Name some organic acids. Explain how an amino acid is formed. How are proteins formed? What happens when a protein is digested? Name some other compounds built by plants.
- C. Why is digestion necessary? What is an enzyme and how does it function? How is the energy content of foods measured? How much energy is in a gram of carbohydrate? of protein? of fat? Which foods are fuel foods? How does a living organism obtain its energy? How is energy used in animals? in plants? How are proteins used in the body? What is an inadequate protein? an adequate protein? Name some minerals necessary in the animal diet. How is a reserve food supply stored in animals? in plants? Define metabolism.
- D. What is the origin of the vitamins? In general, what happens if there is an insufficient vitamin supply in the animal diet? Give a brief account of each of the vitamins discussed in the text and mention foods especially rich in them.
- E. What dangers are there in a restricted diet? If the endocrine glands are working properly, what does overweight indicate? underweight? What is the only way that fat can be removed from the body? Give the principles of a reducing diet. Mention foods that should be included in a reducing diet; foods that should be restricted in amount. What mistake is often made in trying to reduce the body weight? What principles should be followed in selecting a fattening diet? Mention some other important points relating to dietetics. Define allergy. How are tests made for allergy?
- F. Name habit-forming substances commonly used in the United States. What effect have these substances on the metabolism? What effect does a moderate or an excessive use of alcohol have on the death rates? Discuss alcohol as a food. Why should habit-forming substances not be treated as ordinary substances are?

SUGGESTED ACTIVITIES AND APPLICATIONS

- 1. Set a vessel containing water plants in the sun. Place a glass funnel mouth down over the plants and collect by displacement of water a test tube full of the gas given off by the plants. With a glowing splint test the gas to see if it is oxygen.
- 2. Cut a potato in two. Scrape the cut surface and under the microscope examine the scrapings. Among the débris of the torn-up cells will be starch grains. Note the concentric lines on them. The grains are built up layer by layer through the deposition of starch.
- 3. Make chemical tests for starch, sugar, and proteins. Test a number of foodstuffs for these substances. See the workbook for directions.
- 4. Test some starch paste for sugar. Then to a little of the paste add saliva. After 20 minutes test for sugar. Results? Explain.
- 5. Prepare two vessels of water made only very slightly alkaline with ammonia. Add phenolphthalein. The color should be pink. By the use of a glass tube breathe through the water. The carbon dioxide from the lungs neutralizes the ammonia and the solution becomes colorless.

In the second vessel place some water plants. Cover from the light. Is the solution decolorized? Why does this experiment work better in the dark?

According to directions given in the workbook, test a yeast culture to see if it gives off carbon dioxide.

In what process is carbon dioxide evolved? Do all living things carry on this process? What do living organisms obtain through this process?

- 6. Weigh yourself before a meal and again after eating. How much did you gain? If you sat on a scale for several hours without eating or drinking, would you lose weight? Explain.
- 7. Taking into account your age, weight, and the amount of work you do, about how many calories do you need each day to maintain normal weight? Make up a diet that would increase your weight; one that would decrease it.
 - 8. Do you know any foods that give you hives or make you ill?

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unit 15HEREDITY

Journal of Heredity

Offspring resemble their parents because they are made of the same kind of protoplasm.

> "Equally conspicuous with the truth that every organism bears a general likeness to its parents, is the truth that no organism is exactly like either parent. . . . No two plants are indistinguishable; and no two animals are without differences. Variation is coextensive with heredity." HERBERT SPENCER

RESEMBLANCES AND DIFFER-ENCES IN PARENT AND OFFSPRING

OUESTION FOR CLASS DISCUSSION

Is the conclusion to Hans Andersen's story of "The Ugly Duckling" justified?

A CHICK develops in a hen's egg because its first cell is chicken protoplasm. The cell in a duck egg is duck protoplasm, and it grows into a duckling because this is the natural developmental route for duck protoplasm to take. A grasshopper resembles its parents, not because it lives in a field and feeds on grass as its parents did but because it is made of grasshopper protoplasm. If you raised it in a tin box and fed it on apples and bran, it would be a grasshopper just the same. When a famous professor of biology was asked why the offspring resembles the parent, he instantly replied, "Because it is made from a piece of the same stuff." The thought behind this terse response is that the protoplasm of the parent has certain qualities that caused it to develop into a certain kind of being, and that because the protoplasm of the offspring is the same it will grow into an organism of the same kind.

Inheritance in asexually produced offspring can be explained in this simple way, but in sexually produced individuals it is more complex. A fertilized egg is a combination of the protoplasm of two cells. In all the higher animals and in cross-pollinated plants these cells (egg and sperm) are from different parents. There is a mixing of two lines of protoplasm, so that one generation is never made of exactly the same material as the generation before.

Under these conditions we should expect the offspring to be like each parent in some respects and unlike it in others. In those things in which both the parents are alike the offspring should and does resemble them. Dogs of all breeds have four legs, and no matter what breeds of dogs are crossed, the puppies

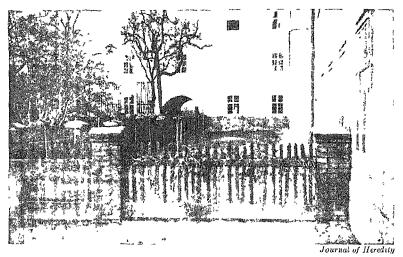
have four legs. But in respect to qualities in which the parents differ the offspring cannot resemble both of them. Will it in these characters be like one parent or the other, or halfway between? Or may the offspring have characters, absent from both parents, that come down to it from its grandparents or great-grandparents, skipping one or more generations on the way? There are definite laws governing the transmission of hereditary characters and these are our subject for study in this unit.

The branch of biology that deals especially with heredity is called *genetics*. Astonishing progress has been made in this fascinating and very practical field of biology, and it has now become a great science in itself. The field was opened for scientific study by Gregor Johann Mendel, who was born on a farm in Austrian Silesia in 1822. He showed so brilliant a mind in his early schooling that his parents decided he must continue his education. He entered a church school, became a monk, and in time was appointed Abbot of Brünn. In the midst of his churchly duties he still found time to grow plants, and in his cloister garden he raised peas and studied inheritance in them.

Problems in Unit 15

- 1 What discoveries concerning heredity were made by Gregor Mendel?
- 2 How are hereditary characters transmitted?
- 3 What important additional discoveries have been made in the field of heredity since Mendel's time?
- 4 Is there a possibility of breeding new and better kinds of cultivated plants and domestic animals?
- 5 How are farm plants and animals bred to secure uniformity and vigor?
- What applications of our knowledge of heredity may we make in human society?

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Mendel's garden at Brunn. Here the science of genetics was born.

PROBLEM ONE

What Discoveries Concerning Heredity Were Made by Gregor Mendel?

The genius of Mendel displayed itself in the way he went at his experiments. He had no great laboratory and no staff of trained assistants; so it was necessary for him to work in a simple way. For his material he chose garden peas — plants that are easily grown, that naturally pollinate themselves and so do not have hybrid strains mixed in them, and that do not require bags over the flowers to prevent cross-pollination by insects. Because scientific research advances by establishing one fact at a time, Mendel did not try to investigate the heredity of the pea in general. He chose sets of contrasting characters, such as white and red blossoms, smooth or wrinkled seeds, or tallness and dwarfness of vine. Then he cross-pollinated plants having these contrasting characters and planted the seeds that contained the cross-bred plants. Thus working in a simple way, he discovered facts and laws of heredity that have wide practical application in

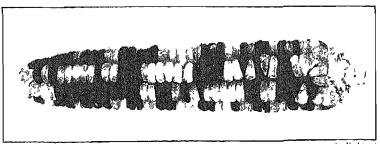
the breeding of plants and animals, and enabled others to go about the study of heredity in a scientific way.

Mendel's discovery. Suppose you should pollinate a white pea with pollen from a red one and plant the resulting seed. Would you expect the flowers on the hybrid plants that grew from the seed to be red or white? Or would you expect the flowers to be pink, which would be halfway between the two parents?

Mendel made this experiment and found that all the flowers of the hybrid were red. The white did not make the flower a lighter red, intermediate between red and white. It was in the hybrid peas, but it did not show; it was covered up, hidden away. Mendel called the red a *dominant* character because it dominated the white. The white he called *recessive*.

Do you see how the white might possibly come out in future generations? In human beings brown eyes are dominant over blue, but two brown-eyed parents each of whom has recessive blue may have a blue-eyed baby. The offspring may inherit the hidden character of the parents and not the dominant one that shows.

Mendel found that other pairs of characters in his peas were inherited in this same way. Smoothness was dominant over wrinkledness in the seed; yellow in the seed coat dominated green; tallness of vine dominated dwarfness. In respect to any particular character picked out, the hybrid offspring was like one



A B Stou

Some of the grains of this ear of white sweet corn received pollen from near-by stalks of Black Mexican corn. The dark color is dominant over the white.

HEREDITY

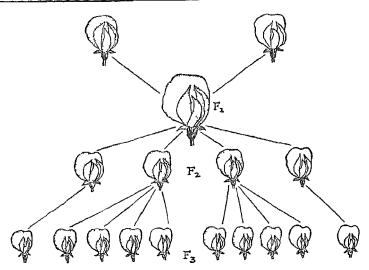


Diagram showing the results Mendel secured by crossing a redflowered and a white-flowered pea and growing the hybrid offspring through three generations. In the diagram the red flowers are indicated by dotting of the petals.

or the other of the parents but was not intermediate between them. It made no difference which plant was the pollen parent and which the seed parent. Pollen from a tall plant on the pistil of a dwarf plant gave the same result as the reverse cross.

Mendel's conclusions. Mendel thought about his experiments and reached some new conclusions about heredity.

First, Mendel decided that in respect to inheritance a pea plant is not a single whole, but is made up of many separate features or units which he called unit characters. These unit characters are inherited independently. The color of the flower had nothing to do with the height of the vine or the plumpness of the seed. The plant is made up of many separate units and each of these is inherited without regard to the others.

Further, Mendel decided that in inheritance a unit character is handed on as a whole. It does not break up so that a pea might get only a half unit. If it did break up Mendel would have found pink flowers in his peas and these he did not find. Before Mendel's time it was taken for granted that a hybrid would be intermediate

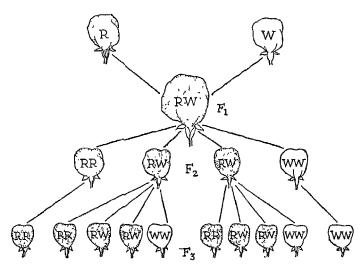


Diagram of the genetic composition of the flowers shown on the opposite page. RR means pure red, WW pure white, and RW mixed red and white.

between its parents. Mendel said that a pea either had the whole unit or it lacked it entirely. Parents pass on a unit as a whole. This is Mendel's *law of independent unit characters*.

Second, Mendel saw that in a hybrid made by crossing parents of two contrasting characters, one character is dominant and the other recessive. He found that in one character a hybrid might be like one parent and in another character like the other parent, but in any one character that he selected it was always like one or the other. One character was dominant and the other disappeared for that generation. This is Mendel's law of dominance.

These ideas of Mendel's were new. Before his time it had been supposed that when two different strains of protoplasm are united in a hybrid they blend as milk and water do when they are poured together. Mendel believed that, in respect to heredity, when two protoplasms are united it is like the stirring together of white and yellow grains of corn or of beads of different colors. He introduced the conceptions of unit characters and of dominance and recessiveness; and he stated that in respect to any one

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character in which the parents differ, the offspring is like one or the other parent and not intermediate between them.

Second-generation hybrids. What happens in the second generation of hybrids? Do the units stay separate? Mendel carried on his experiments to find out. He let his hybrid peas fertilize themselves, which was really the same as breeding together two hybrid plants, and then found what kinds of plants the seed would produce. For example, he saved and planted self-fertilized seed from red hybrids that carried white as a recessive. What do you suppose he got?

Mendel was trained in mathematics and he was exact. He counted the plants and noted the colors of the flowers, and he found that approximately one fourth of the plants of the second generation had white flowers. They were as white as if they had never been crossed with the red. When the seed from them was planted they bred true white, on and on. The red character was permanently gone.

The other three fourths of the plants of the second generation had red flowers. They all looked alike, but when the seeds from them were planted they proved to be of two different kinds. One fourth were pure red. The seeds from them all gave plants with red flowers. They were as pure red as if the white had never been crossed in. The white in them was gone.

The remaining two fourths of the second-generation hybrid plants had red flowers, but these proved to have recessive white in them. The seed from them when planted proved to be exactly like the seed of the first hybrid generation — one fourth of the plants from their seed had white flowers, or were pure recessives; one fourth were pure reds, or dominants; half were red with recessive white.

The ratio between pure dominants, hybrids, and pure recessives in second-generation hybrids Mendel found to be 1 to 2 to 1. The diagrams on the preceding pages show his results. R in the diagram stands for red and W for white. F_1 means the first hybrid generation and F_2 the second generation. White is marked as being in the plant, even though it is recessive and does not show.

Mendel found that the same laws applied in the inheritance of other characters as in the inheritance of flower color. Smoothness of seed and tallness of vine were inherited like the dominant red. Wrinkledness in the seed and dwarfness of vine were inherited like the recessive white.

Explanation of throwbacks. Have you heard of throwbacks in heredity? An animal or a person may in some way resemble, not his parents, but ancestors farther back. In some character an individual may go back or "throw back" to an ancestor of an earlier generation. Do you see how Mendel in his peas had throwbacks to the grandparents?

In flower color one fourth of the peas were pure red like one grandparent. One fourth were pure white like the other grandparent. The remaining half were hybrids like their parents. The flowers were red in color, with the white recessive in them.

If you bred the hybrid peas on for twenty generations in large enough numbers to keep all the lines running you would still have in each generation some hybrids—red in color but carrying recessive white—that would give throwbacks to the original white kind with which you started.

A throwback may be produced by an individual's going back in one character to the kind of protoplasm that was in the line before the hybridizing was done. White is dominant in sheep. A black sheep from white parents is a throwback. It is one in which the white dropped out and let the recessive black inherited from earlier ancestors appear. It is easy to tell when a dominant character is lost because the recessive then shows itself. The one way to tell whether a recessive character is present or has been lost is by the "progeny test." Plant the seeds of a red pea, and if no white-flowered plants appear you know that the white has been lost.

Units in new combinations. Suppose you cross a dwarf white pea and a tall red one. Redness and tallness are dominant; so all the first-generation hybrids will be red and tall. If these hybrids are now bred together you will get in the second generation all kinds of combinations — red-dwarf, white-dwarf,

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red-tall, and white-tall. Leaving out of account the ones that carry a mixture of dominant and recessive units, you will have four kinds that will breed true.

Moreover, if you wish to take account of the wrinkledness and smoothness of the seed you can have four kinds more. Suppose your peas are smooth and you hybridize them with a wrinkled variety; you can then get the four kinds we have mentioned above with either smooth or wrinkled seeds, making eight kinds in all. By building in these units in different combinations you can breed peas of many different kinds.

Practical applications. Do you see how Mendel's discoveries can be used in breeding plants and animals? Here is a tomato plant that is a heavy yielder of fruit, but it blights. Here is another kind that is blightproof but yields a small crop. Cross them and get both the resistance to the blight and the heavy production into the same plant. If the fruit is not as solid as you wish, cross it again with a kind that excels in solidity and add this quality to your creation. If the desired characters are recessive and disappear in the first generation, do not be discouraged but keep on, for we know that in second- and third-generation hybrids all kinds of combinations of the characters appear. Since Mendel showed how to work for one unit at a time, plant and animal breeders have done wonderful things.

Mendel presented the results of his work to the Brünn Natural History Society and in 1865 his papers were published in a little magazine that the society issued. Most of the biologists who might have appreciated these great discoveries did not hear of them, and those who did read the reports failed to appreciate their importance. Mendel was disappointed, but he would say: "Mein Zeit wird schon kömmen!" (My time will surely come!) It did come, indeed, but not until 1900, sixteen years after Mendel's death. Then three different investigators, looking up what was in print about the problems on which they were working, came on his papers and immediately called them to the attention of the scientific world.

Now Mendel's time has come. In the second half of the nine-teenth century there were men in positions of great prominence and power in Austria, and Mendel seemed comparatively unimportant — merely the head of the monastery at Brünn, whose hobby was working in the garden with his peas. In reality Mendel was the truly great figure that Austria was presenting to the world. The supposedly important ones who were employed with temporary matters are gone and not missed. Mendel's discoveries are enriching all mankind and the benefits that flow from them are but a thin trickle when compared with the floods that are to come. One of the pleasant things about scientific discoveries is that their benefits are shared by the peoples of all nations and by generations that live after the discoverer is gone.

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PROBLEM TWO

How Are Hereditary Characters Transmitted?

You may plant wheat and oats together. The soil is identical; the water supply, sunshine, and air conditions for all the plants are the same. Yet from the wheat grains wheat plants grow, while the oat grains produce nothing but oat plants.

What is there in the wheat grain that causes a wheat plant to grow from it? You say that there is an embryo wheat plant, and you are right. This embryo grew from a single cell (the fertilized egg) just as the embryo oat plant in the oat grain grew from a single cell. If we wish to find the reason for the differences in the plants, we must look for the explanation in the single cell from which each plant developed. The cell is the biological unit, and in biological studies we can never get far from it. In heredity it is to the cell nucleus that our chief attention must be given.

The cell nucleus. In a piece of tissue stained for examination with the microscope, you will have no difficulty in seeing the nuclei of the cells. In a "resting cell" (one that is not dividing) the nucleus consists of a network of material, the *chromatin* (krō'ma-tǐn; Greek *chroma*, color), that stains more deeply, and a lighter, more fluid material, the *nucleoplasm*, in which the chromatin network is embedded. The chromatin appears as a planless tangle of fine threads and granules; but when the cell gets ready to divide, the chromatin gathers together into curved or rodshaped bodies. Each of these bodies is called a *chromosome*. By double staining (using two stains) the chromosomes may be given a different color from the other materials of the cell.



In the resting cell nucleus (left) the chromatin is spread out in a fine network. During cell division it is gathered into rod-shaped bodies that are called chromosomes. After the division is completed the chromatin again spreads out into a network in the new nucleus.













When a cell divides, each chromosome splits lengthwise and one half of it goes to each of the new cells. Each daughter cell has exactly the same chromosome equipment as the mother cell.

Any particular species of plant or animal has a definite number of chromosomes in the nucleus of each cell of its body. In your body each cell contains forty-eight chromosomes. Each cell in the body of a cat, a wheat plant, or a birch tree contains sixteen chromosomes. The number is twenty-four in the edible snail, in the tomato, in one kind of lily, and in many species of grass-hoppers. One species of Ascaris (a roundworm) has only four chromosomes in each cell. The housefly has twelve, the earthworm thirty-two, and the rat thirty-eight.

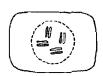
Chromosomes in cell division. When a cell divides each chromosome splits lengthwise, thus doubling the number. Then one half of each original chromosome moves to one end of the cell and the other half of each moves to the other end. Thus there are two groups of chromosomes in the cell.

The chromosomes of each group next branch out and form the chromatin network that we see in a normal resting nucleus. A cell wall comes in between these two new nuclei and there are two cells where there was only one. Each daughter cell has the same number of chromosomes as the original cell and what is more, each chromosome in the daughter cell is exactly half of an original chromosome of the mother cell. In the newly formed cell each chromosome grows to full size and at the next cell division splits lengthwise again.

Although the chromosomes all seem to blend together in the chromatin network of a resting nucleus, each one nevertheless maintains its identity. When it comes time for a new division the same chromatin that was in a chromosome before it spread out into the resting nucleus gathers together and forms the chromosome again. A chromosome in the resting nucleus exists in a finely branched condition and during cell division in a rod-

like form, but in either condition it remains separate from the other chromosomes.

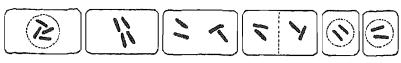
Two sets of chromosomes. An organism produced by sexual reproduction has two sets of chromosomes in each cell; it begins life this way. An egg has one set received from the mother. In fertilization a second set is brought in by the sperm. The chromosomes in the fertilized egg arrange themselves in pairs. Each chromosome from the male parent pairs off with one from the female parent; at times of cell division we find the two chromosomes of a pair lying side by side. We know that this is true because in some hybrid crosses of both plants and animals the chromosomes of the two parents differ enough in size and shape to be distinguished under the microscope, and always



In the nucleus of a cell there is a double set of chromosomes, one set derived from either parent. we find that a chromosome pair consists of one chromosome from each parent.

An organism has, therefore, a double set of chromosomes — one set from either parent — in each of its cells. The chromosomes arrange themselves in pairs, and in cell division each chromosome divides and a new chromosome pair is passed on to each of the daughter cells. When we study heredity we are studying the combined effects of chromosome pairs and not of single chromosomes.

The reduction division. Why is not the number of chromosomes increased when an egg is fertilized by a sperm? The regular number of chromosomes in the grasshopper is twenty-four. If a grasshopper egg carried twenty-four and the sperm



In the reduction division, which occurs before the sperms and eggs are formed, the chromosomes do not divide. Half of them go to each of the new cells, so that the new cells have only half the original chromosome number. When the egg and sperm unite, the chromosome count is raised to the original number.

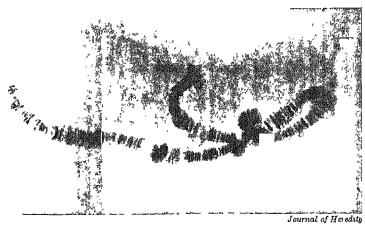
twenty-four, would not the fertilized egg have forty-eight chromosomes? And would not this doubling of the chromosome number start a new kind of grasshopper with twice as many chromosomes as either of its parents? The number of chromosomes in the offspring is kept down to the same number that was in each parent in the following manner:

When the sperms are formed there is one division of the sperm mother cell in which the chromosomes do not divide. Half of them simply move to one end of the cell and the other half to the other end. The nucleus of each of the new cells has only half the original number of chromosomes.

Similarly, in an egg before fertilization there is a division of the nucleus without chromosome division. Two nuclei are formed within the egg, each with only half the original number of chromosomes. One nucleus moves toward the outside and is "thrown out," or goes to the outside of the egg. The nucleus left in the egg contains only half the original number of chromosomes.

The sperm of the grasshopper has only twelve chromosomes and the egg has twelve. When the sperm and egg unite, the fertilized egg has the original number — twenty-four. The new grasshopper has only the regular number of chromosomes in its cells.

The cell division in which the number of chromosomes is



Photograph of a chromosome, greatly enlarged.

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reduced is called the *reduction division*. If it were not for this reduction division, fertilization would double the number of chromosomes each generation and parents would doubtless see offspring strangely different from themselves.

Heredity in chromosomes. Suppose now that you could put a very high-power microscope on a single chromosome and examine it carefully. You would find that it appears to be made of a string of chromatin granules placed together much as freight cars are coupled together in a long train or as beads are threaded on a string.

These granules are the carriers of Mendel's unit characters. They are, or contain, the determiners of heredity. When a chromosome splits in cell division each granule is split through the middle and the two new chromosomes from end to end are exactly alike. After the division each granule grows to the size of the original one; so through generation after generation of chromosomes and cells and organisms the granules live on and on. Into the cells of the offspring goes directly and literally the "same stuff" that the cells of the parents bore.

Genes. The chromosomes of a fertilized egg cannot contain the characters that will be shown by the adult organism that grows from the egg. An egg in the ovule of a pea cannot contain the red flower or the tall vine of an adult pea plant. A frog's egg cannot contain the green back and the strong hind legs of the frog. A mammalian egg cannot contain the four-chambered heart, the air-breathing equipment, and the hairy coat. All that the egg can contain is the determiners of these things — something in the granules of the chromosomes which causes these characters to develop in the embryo.

In discussions of heredity these determiners are commonly called *genes* (jēns). Mendel's peas had genes that determined whether the plants would have red or white flowers, smooth or wrinkled seed, long or short stems. A gene is the determiner of a hereditary unit character. The genes for different characters may be in different chromosome pairs. One pair of chromosomes may contain the genes for the color of the eyes, another pair the

genes for the shape of the nose, and another for the capacity of the mind.

Two sets of genes. In an organism each cell has a double set of genes, one set in each of the chromosomes. If for any unit character (for example, the flower color of a pea) the genes of both sets are of the same kind, the adult plant or animal will show the character they produce. If the two genes differ (as when one is a determiner for a red and the other for a white flower), one of them dominates the other. In hens and in sheep the gene for white dominates the one for black. In human beings the gene for dark eyes dominates the one for blue, and the one for normal hearing dominates the one for deaf-mutism.

All of us, therefore, are double beings. We carry a set of genes that show and a lot of recessive genes that are hidden by the functioning ones. The modern student of heredity thinks of a chromosome as a chain of genes and of each cell as having a double set of these genes.

Differences in F_2 hybrids. In the second hybrid generation Mendel found that some of his peas were pure red, some were pure white, and some were red with the recessive white concealed. The discovery of chromosomes and genes and the fact that in the reduction division the chromosomes are distributed without first dividing gives us an explanation of these three kinds of F_2 hybrids.

Mendel's F_1 hybrids were made by crossing a red-flowered and a white-flowered plant. In such a hybrid plant each cell contains one gene for red and one for white. One member of the chromosome pair that carries the flower-color determiner has a gene for white and the other a gene for red. In the reduction division the chromosomes do not divide, but one of the pair goes to each of the new cells. In consequence, half of the eggs and half of the sperms will contain the gene for redness and the other half will contain the gene for whiteness. Show by a diagram that an egg or a sperm carries the gene for either whiteness or redness but not for both.

Suppose a sperm with a red gene unites with an egg that also carries a red gene. Then the new plant will be pure red. The

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white is lost from it entirely. Each cell has a double set of red genes. It can produce only eggs and sperms that carry red genes and it will always breed true red. Similarly, if a sperm and an egg that both carry white genes unite the plant produced will be pure white, and if a white and a red gene come together the new plant will be red with the white recessive in its cells.

You will readily see that there are only three possible combinations of the red and white genes, RR, RW, and WW. These combinations produce the three kinds of F_2 plants that Mendel found.

The 1:2:1 ratio. Half the gametes (eggs and sperms) from a first-generation hybrid red and white pea carry the gene for redness and half the gene for whiteness. When they unite in fertilization it is a matter of mere chance whether the eggs and sperms that come together have the color genes alike or different. They can mate up so that the genes in the fertilized egg are RR, RW, or WW. By the laws of chance in any considerable number of cases the ratio of the pure red, red-white, and pure white combinations will be about 1:2:1. You can test this law for yourself in the manner suggested on page 702.

As Mendel found, one out of every four plants in the second or F_2 hybrid generation has white flowers. It is a pure white because it carries a double set of genes for whiteness in its cells. The other three plants have red flowers. One of these three carries two genes for redness and is pure red. The other two have recessive white in them. The next generation (F_3) of an RW plant will produce some plants with white flowers just as an RW plant in the F_1 or F_2 generation does.

Changes in the chromosomes. There may be changes in the chromosomes; a character may drop out or a new one develop. The change may come all at once and after the character appears it is inherited as a dominant or a recessive as other characters are. The illustration shows an ancon (ăng'kŏn) sheep, a specimen of a breed that was established from a single short-legged individual that appeared in the flock of a Massachusetts farmer. The farmer considered the short legs an advan-

tage because the sheep could not so easily jump out of the pasture; so he kept the offspring of the sheep and from them built up a short-legged breed.

New types of plants and animals that differ distinctly from their parents because of changes in their chromosomes are called *sports* or *mutants* (Latin *mutare*, to change). The changes are called *mutations*. Many new varieties and breeds of plants and animals have been established from chance mutations.



The ancon sheep. It is a short-legged type which appeared as a sport or mutation in a Massachusetts farm flock.

Hornless varieties of nearly all breeds of cattle have been developed from individuals that appeared without horns.

Thus through a study of chromosomes and of chromosome behavior we find an explanation of the facts of heredity which Mendel observed. We see why offspring may be like their parents in some respects and different from them in others. You will understand, of course, that all Mendel's findings and the explanations of them apply only when there is sexual reproduction. In asexual reproduction there is no cell division where the chromosome number is reduced, and no union of cells to give new combinations of chromosomes. The offspring produced by asexual reproduction goes on with the same chromosome setup as the parent and in all ordinary cases is like the parent.

PROBLEM THREE

What Important Additional Discoveries Have Been Made in the Field of Heredity since Mendel's Time?

In the two preceding problems we have considered a very simple theory that explains the facts of heredity which Mendel found in his peas. The trouble in applying the theory universally is that inheritance does not always carry along in a simple way, but often becomes complicated and goes to unexpected ends. Mendel's ideas must be extended and qualified to make them fit all the cases that arise.

Seeming intermediate hybrids. Mendel's law of dominance states that in any given unit character the offspring is like one parent or the other; it is not intermediate between them. There are, however, red-flowered and white-flowered four-o'clocks that when crossed produce a pink-flowered offspring. A cross between a Black Minorca fowl (a large breed) and the Leghorn (a small breed) gives a hybrid smaller than one parent and larger than the other. If one unit or the other dominates how do we

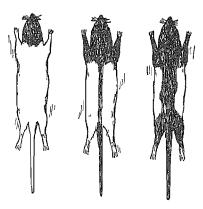


account for these intermediates? In three ways.

1. Imperfect dominance. Many examples of imperfect dominance are known. When a red and white cross gives pink the red does not dominate the white completely, but is more feeble than when both the genes are red. Mendel's law of dominance holds in some cases and in others it holds only in part. That in the pink four-o'clock there is no mixing of genes is shown by the fact that in the F_2 generation one fourth of the offspring

A zebra-ass hybrid mule. The fact that it is intermediate in size and coat markings between its parents seems inconsistent with the theory of Mendelian heredity.

are white, one fourth red, and one half pink. The reappearance of the pure red and white lines shows that the genes are not blended in the pink flowers but remain separate. This leads us to the conclusion that some hybrids are intermediate between the parents because one gene only partially dominates the other.



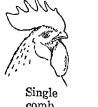
Hooded rats, showing variation in the intensity of the hooded character.

- 2. Varying intensity in a character. A character may show itself with more or less intensity; there is always variation in living things. The hooded rat has typically the top of the head and the upper front half of the body black, but you can select and breed a strain of rats in which the black is only on the head and another strain on which the black extends back to the tail. All have the gene for black. But in some the black displays itself more than it does in others. This is because the effects of a gene are modified by the other genes of which the organism is made up. This fluctuation in the intensity of a character may make it seem that in hybrids there is every degree of intermediacy, and it may make more difficult the decision as to what the real units are.
- 3. Multiple units. Many hereditary characters are in reality made up of two or more smaller unit characters. Darkness of human skin color, for example, seems to be the result of about four units or pairs of genes. If one is present the skin is to an extent darkened. If two are present the effect of the second is added to that of the first and a darker color results. Similarly, three units give a still deeper pigmentation and four result in the deep black. There are intermediate skin colors, but the gradations go by steps and these steps are the real unit characters. An intermediate size resulting from the crossing of a larger with a smaller breed of animals is explained by the assumption that size is not determined by a single pair of genes but by a number of them.

In studying heredity in any organism, one of the first tasks is to determine what are the independent units that will separate themselves out in the reduction divisions. These are usually more numerous and represent finer distinctions than one would at first suppose. If you had a hen that laid a pure white egg and another that laid an egg of a deep brown, your first thought might be that one hen had a brown gene and that the other lacked it. Actually there are several brown genes, and you can breed hens that will lay eggs of varying colors from only a slightly creamy tint to a deep brown.

Cumulative genes. In some cases two genes are necessary to cause the development of a character. Two kinds of white sweet peas have been found that when bred together produce colored flowers. Two strains of white fowls are known that when crossed give offspring with highly colored plumage. When we begin hybridizing we are likely to get characters that neither of the parents has. This fact is explained by the assumption that each parent has something that alone will not produce the character, but when the two are put together they do produce it.

Again, a character may appear because new genes are added to a gene that is already functioning. A fundamental comb gene gives the ordinary single comb in a fowl. A gene added to this makes a pea comb; a different gene added to it makes a rose comb; and when both these genes are added to the fundamental gene they give a walnut comb. If you become a geneticist you will learn much of how additional genes cause previously absent characters to appear and modify those that already exist.



comb



Pea comb



Rosecomb



Walnut

Cumulative genes. A single fundamental gene produces a single comb. An additional gene gives a pea comb. A different additional gene produces a rose comb. When both additional genes are present a walnut comb results.

Inheritance of sex. In the unisexual animals sex is a unit character. Either maleness or femaleness is inherited, just as redness or whiteness is in the pea. The explanation of sex inheritance and of the 1 to 1 ratio between the sexes is in the chromosomes.

The insect *Protenor* (a close relative of the squash bug) illustrates sex differences in chromosome equipment. The female has fourteen chromosomes in the cell and the male has thirteen. All the eggs before fertilization have seven chromosomes, but in the male, when the reduction division occurs before the sperms are formed, seven of the chromosomes go to one sperm cell and six to the other. This results in the formation of two types of sperms,

one type with seven chromosomes and one with six. If an egg is fertilized by sperm carrying seven chromosomes it develops into a female. If it is fertilized by a sperm with six chromosomes it develops into a male. Whether the fertilized egg develops into a male or a female depends on the number of chromo-

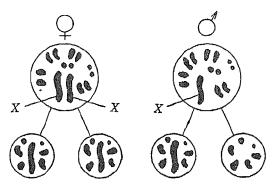


Diagram of the chromosome composition of the female and male of the insect *Protenor* and of the formation of the eggs and sperms. The male has one less chromosome than the female and two types of sperms are formed. Further explanation of the diagram is in the text.

somes it receives. The number of sperms of each of the two types produced is equal; so the number of eggs fertilized by each kind and the number of males and females developed are approximately equal.

In the human body cells there are forty-eight chromosomes—twenty-four chromosome pairs. In the female, in each of the twenty-four pairs the two chromosomes are equal in size. In the male, the two chromosomes are equal in twenty-three of the

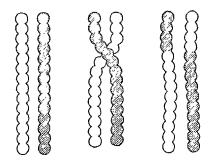


Diagram illustrating crossing over. Genes that were in one chromosome may become part of another.

parent. At times the chromosomes lie crossed over each other, and when they are separated in the reduction division they sometimes break at the crossing. Then each chromosome takes the end of the other one and thus some of the genes that were in one chromosome are moved over and linked up with some that were in another. This transfer of genes is called *crossing over*.

Defective chromosomes. A chromosome may have a defective or undesirable recessive gene, or perhaps it may lack a

gene that normally it should have. This may do no harm to the developing individual if the other chromosome of the parental pair has the desired gene, for a single gene may be enough to cause the normal development of a character. It is evident, then, that a defective chromosome mated with one that has a complete set of desirable genes would provide at least one good gene for each character. The diagram on the right shows how even two defective chromosomes might together make up a complete set of normal genes. For normal development the important point is that the chromosomes shall not be defective in the same gene.



Diagram of chromosomes with defective genes in black. Which pair will furnish a complete set of normal genes?

Because a single gene of a pair can cause normal genes? normal development, defects can be covered up in inheritance. In human inheritance many defects are thus covered up. The children of a normal and a feeble-minded

¹ Possibly the difficulty is the presence of undesirable recessive genes, possibly it is the absence of genes. For example, feeble-mindedness may be thought of as resulting either from the lack of a gene to cause the development of the mind or as the presence of a gene that prevents its development. The chromosomes and genes are spoken of as defective, without implication as to the nature of the defect.

person are usually normal. Deafness may be inherited, but the children of a parent with deafness of an inherited type and of a person with normal hearing usually have normal hearing. The defects are inherited as recessives, and they show themselves only when both chromosomes of the parental pair are defective in the same genes. In great numbers of persons there are defects inherited from one parent that are hidden by a normal inheritance from the other parent.

Variations from ordinary cell divisions. In asexual reproduction there is only one parent organism. The young is a piece of this parent. It ought to grow into an organism exactly like the parent, and in all ordinary cases it does. A cutting from a branch of a plant will give a plant of the same kind as the one from which the branch was taken, and nurseries guarantee the grafted and budded stock they sell as being true to name.

There is, however, such a thing as variations or sports that originate in ordinary cell division. Viruses and bacteria may change. The flowers of a petunia or four-o'clock on one branch may differ from those on another. A branch of an apple tree may produce apples of an unusually brilliant color, and strains of apples of higher coloring than the parent strain (e.g., Red MacIntosh, Red Rome) have been established by using cions from such branches. Sexual reproduction, with the mixing of protoplasm it brings, is undoubtedly favorable to variation, but changes can take place in the cells as they undergo ordinary vegetative growth. Only recently has there been general recognition of the fact that these vegetative sports do appear. Now occasionally a new type of fruit is established by the propagation of one of them.

Other interesting examples of variation in connection with ordinary vegetative cell multiplication are found in certain insects in which the two sexes differ in size or appearance. In most of these insects the female has one more chromosome than the male, and the most common variation is for some of the cells of the female body to lose a chromosome and change from the female to the male sex. If the chromosome is lost in an early cell division, one half or one quarter of the body may be male and the remainder

female. If the loss of the chromosome is later, there may be only a patch of male cells. If one sex is winged and the other is not, there may be wings on one side of the body and none on the other.

Causing variations. Many of the improved varieties of domestic animals and cultivated plants have come into existence as chance sports or new forms. All at once an individual appeared that was decidedly different from its parents, and by breeding from this individual a new variety or strain was started. Biologists have long been interested in the origin of these sudden variations. If plant and animal breeders could cause new forms to appear in great numbers they would be likely to find among them improved forms for agricultural use.

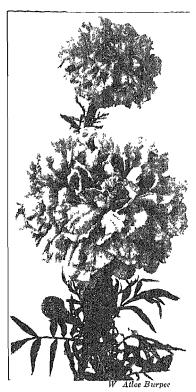
It has been found that X-raying fruit flies increases the variations among them. It is reported that exposing the flies and eggs to sudden and great changes of temperature has the same



J. Horace McFarland

The autumn crocus (Colchicum) from the bulb of which colchicine is extracted.

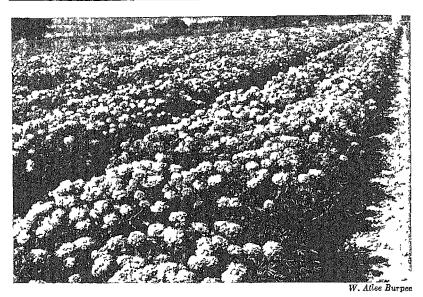




At the left a young plant is being dipped in a solution of colchicine. At the right above is a marigold flower of the original variety, and below the much larger flower produced by increasing the number of chromosomes.

effect. A much more important discovery is that in plant heredity a chemical called colchicine (kŏl'chĭ-sēn) acts as a veritable genetic dynamite. This chemical is extracted from the bulb of a plant of the lily family (*Colchicum*). It is highly poisonous and has been used in human medicine in the treatment of lumbago and gout.

If a bud or a branch of a plant (or a whole young plant) is sprayed or painted with a solution of colchicine or is dipped in the solution, the number of chromosomes in the cells in the branch may double in number, or even double again, giving four times the original number of chromosomes in each cell. The



A field of tetra marigolds, plants with four times the original number of chromosomes.

gametes produced on such a branch carry a corresponding increase in the number of chromosomes; so it is possible to establish new plant races with multiplied chromosome numbers. The plants with the increased number of chromosomes show great vigor and a remarkable increase in the size of flowers and fruits. Fertile hybrids are produced by crosses between plants that ordinarily give sterile hybrids. A whole new field of plant breeding has been opened by the discovery of the effects of colchicine on the cells.

In this problem we have noted some of the important facts of heredity that have been learned since Mendel's time. Genetics is a young science, but it has advanced so rapidly that it has already become a very great one. In the next two problems we shall consider the possibilities of improving our domestic animals and cultivated plants through the application of methods and ideas of this highly practical branch of biology.

PROBLEM FOUR

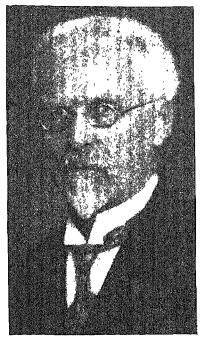
Is There a Possibility of Breeding New and Better Kinds of Cultivated Plants and Domestic Animals?

Agriculture is the greatest and by far the most important of all our industries. In recognition of this fact there is in each state a college of agriculture and an agricultural experiment station. In these experiment stations, and on the experimental farms maintained by the United States Department of Agriculture in various localities, many scientific workers are engaged in attempts to improve our animals and plants. Similar

work is constantly carried on by seedsmen, nurserymen, and live-stock breeders everywhere. The best way of finding an answer to our problem is to consider some of the results that those who have attempted to improve plants and animals have secured.

Hardy fruits for the Northwest. When the Dakotas and Manitoba were settled, practically the only fruits the pioneers had were the wild fruits of the region. The apples, peaches, pears, plums, apricots, blackberries, and grapes of the East were killed by the winter cold. A farm home without fruit trees about it is incomplete. Could anything be done about this situation?

Professor Niels E. Hansen was appointed to the faculty of the State College of South Da-

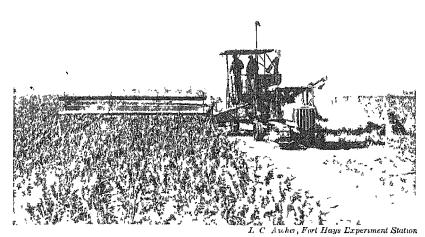


Professor Niels E. Hansen, a notable creator of new plant forms. He produced a whole array of hardy fruits and hardy roses for our Northern plains area and made that region a better and more beautiful place in which to live.

kota, and he did something. He had, been a plant explorer for the United States Department of Agriculture and for South Dakota and had visited many countries, especially European Russia, Siberia, and Turkestan. He knew that there were plenty of fruit-bearing plants more hardy than the ones that had come from western Europe. He made additional journeys into northern Eurasia to find fruits that would endure Dakota cold, and he also brought in the wild fruits of the Dakotas and Canada and used them in his breeding work or as stock from which to select new forms.

Professor Hansen hybridized a native dwarf cherry with the Japanese plum and secured splendid new fruits that are now cultivated from Texas north into Manitoba. He crossed the wild plums of Dakota and Canada with the Japanese plum and Chinese apricot, thus producing hardy plums of large size and choice quality. He crossed the wild grape of the Dakotas with Eastern He hybridized the wild American crab apple and the Siberian crab apple with the standard American apples, with the result that hardiness, large size, and good quality were combined in the hybrids. Professor Hansen, by selection among many seedlings, greatly increased the size of the native sand cherry and by crossing cultivated roses with the wild kinds he produced thornless, hardy varieties of great beauty. He did not need to worry about his plants' coming true from seeds. A single plant of the kind he wanted could be multiplied indefinitely by grafting or budding or by cuttings or new plants from the roots.

New crops for the West. In Oklahoma and in southern and western Kansas the middle of the summer is likely to be hot and dry. In the earing time corn may be caught by heat and drought that it cannot withstand. Kaffir corn and sorghums grow despite the heat, but the varieties that were originally grown were hard to harvest. What was needed was an easily harvested crop that would provide winter fodder and grain for feeding animals. Small sorghums that could be harvested with wheat machinery were bred. Another region had a crop adapted to its climate. The Northwestern dry area likewise has its crop prob-



Harvesting sorghum in Kansas Sorghums withstand heat and dryness that are destructive to corn. Small varieties have been bred that can be harvested with wheat machinery.



Farm Journal

A crop for our Northwestern dry area The photograph shows a hybrid grass made by crossing a perennial wild bunch rye grass and winter wheat. The wild grass has perennial roots that are adapted to dry soil, but it is unappetizing to farm animals and grows only in small bunches. The hybrid grass branches more profusely, is relished by cattle and sheep, and some plants have been secured whose roots live over winter. It is hoped to establish a new kind of plant with far-reaching perennial roots and a top part desirable for pasture and hay.



U. S. Dept. Agriculture

Lespedeza, an invaluable forage and soil-building crop for parts of the South. The illustration shows perennial lespedeza (Sericea) on the United States Experimental Farm at Arlington, Virginia. The plot has grown luxuriantly without fertilizer for 12 years in thin and acid soil.

lems, and a new forage plant that is being prepared for it is shown on page 677.

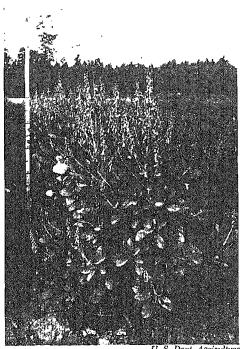
Crops for the Southeast. Our Atlantic states have an East Coast climate corresponding to the climate of eastern Asia and not to that of western Europe. In the southern

part of this area there is a long drought in the latter half of the summer and in the fall. Most of our cultivated plants are from Europe and do not do well in this climate. Cotton is from Asia, and it grows on through the dry period. The soy bean is from Asia, and it has been useful to the farmers of this region. Now Asiatic lespedezas have been introduced, and they not only withstand the drought and heat but flourish in acid soils. They enrich the soil as clover and alfalfa do in other sections and furnish pasture at a time when the grass is gone. Another region has a new and much needed crop. Different varieties of lespedezas suited to different conditions are being selected and introduced.

But across the Carolinas and extending into Georgia there is a great sand belt, and lespedezas do not grow well in sand. Two young scientists were asked to consider what might be done to improve these lands. They found that in Florida a legume called *Crotalaria* was being grown and was proving highly useful on sandy lands. Farm animals will not eat Crotalaria, but it seeds itself like a weed and it is a great improver of the soil. The difficulty in growing Crotalaria in the South Atlantic states was

that it came from the tropics and the season in the Carolinas and Georgia was not long enough to allow it to mature seed.

The scientists knew that other tropical and semitropical annual plants (corn, melons, tomato) have been moved to regions with shorter seasons by developing quick-growing, early-maturing varieties; so they began looking for quickmaturing varieties of Crotalaria. They planted . Crotalaria in the Carolinas and found individual plants that produced They saved some seeds.



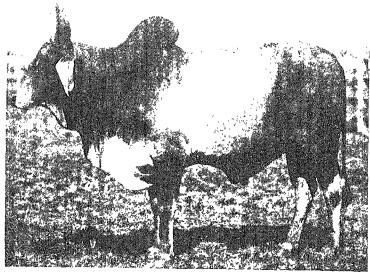
U. S. Dept. Agriculture

Crotalaria, a legume soil enricher for the Southern sand belt.

these seeds, planted them, and soon had an early-maturing strain. Now the farmers of the Carolina-Georgia sand belt have a legume suited to their climate and soil.

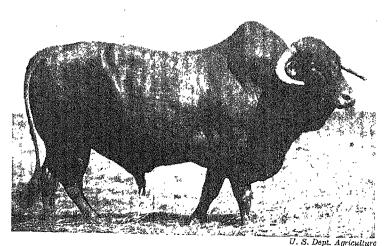
Other plant-breeding results. There is a root-rot disease of sweet corn that sometimes destroys most of the crop, but hybrids resistant to it have been found. Varieties of cotton resistant to wilt have been bred, and of cabbage immune to In infected land these give full crops where other varievellows. ties completely fail. Rust-resistant wheats are being produced, barley is being adapted to the South, pasture grasses and field and garden crops are constantly being improved.

Nor are the fruits being neglected. Nearly all cultivated varieties of apples, peaches, and pears are chance seedlings. Someone found a tree that bore good fruit and propagated it by

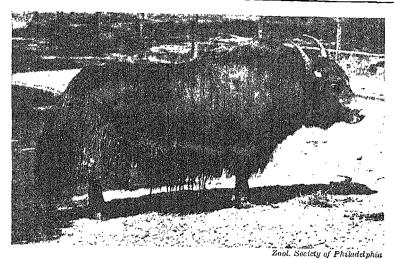


U. S. Dept, Agricultur

The Brahman or humped cattle (zebu) of India and other countries of the Orient are immune to some diseases that our cattle have and withstand heat far better than the cattle of European descent.



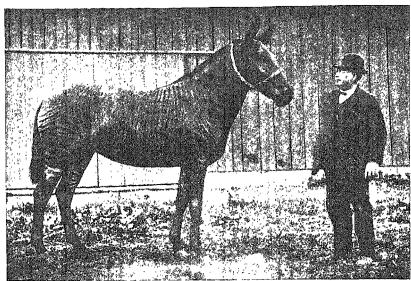
An Afrikander bull, one of a breed that promises to be useful in building varieties of cattle suited to our warmer areas.



The yak of Tibet, whose home is on the roof of the world. It resists almost any degree of cold and grows fat on the sparse vegetation of its native plateau. Doubtless its genes could be used advantageously in building breeds of cattle suited to cold regions.

grafting or budding. Now some of our agricultural experiment stations are breeding peaches and have obtained many new varieties, some of them delicious and of much commercial promise. Other stations are breeding apples and have many new varieties combining the good qualities of two or more of the old kinds. New kinds of plums, berries, grapes, and other temperate-climate fruits are also being produced. The orange has been crossed with the tangerine and grapefruit to give new citrus varieties. Superior kinds of avocados and other subtropical fruits are being bred. The field is wide open and wherever capable workers enter it they get results.

New flowers also are being created from old. The common day lily is so easy to grow that it sometimes runs wild, but it is a coarse plant, and not especially attractive. It does not produce seed but multiplies vegetatively. At the New York Botanical Garden all the known kinds of day lilies from all over the world—some forty-odd species—were gathered together and hundreds and hundreds of cross-pollinations between them were



Journal of Heredity

A zebra mule. The hybrid between the zebra and the horse is larger than the ordinary mule (horse and ass hybrid). It is always chocolate brown in color, with the faint striping shown in the illustration.

made. Most of these pollinations gave no results, but some crosses did produce a number of seeds. These were planted and a whole regiment of new kinds of day lilies — some exquisitely beautiful — were produced. The day-lily genes were arranged in new combinations and new kinds of plants were the result.

Get a seedsman's catalogue and look at the many varieties of sweet peas, columbines, irises, and other flowers. New kinds produced by new combinations of the genes appear each year. There is no limit to the number of new varieties that can be produced.

Improvement in domestic animals. Our domestic animals also are being improved. Hens are made to lay more eggs and cows to give more milk, and there are promising long-time experiments in animal breeding that should be put under way or, where they are already started, kept under way. The humped cattle of the Orient are larger than our cattle and are immune to some diseases that ours have. They have functioning

sweat glands instead of the rudimentary ones of the cattle of European descent and so withstand heat much better. They are being tried for hybridizing and it is now certain that they contribute genes that will be helpful in breeding cattle for the hot parts of our country. There is a kind of large red cattle in South Africa ("Afrikanders") that is being tried in the hot marshes of southeastern Texas and these cattle also promise to be better than our breeds for the lowlands of the South. The illustration on the opposite page shows a new kind of mule, and many other projects in animal breeding are under way.

Opportunities in plant and animal breeding. The chemist builds a few kinds of atoms together in different combinations to make varnishes, lacquers, dyes, perfumes, drugs, alloy metals, and hundreds of other products hitherto unknown to man and suited for almost any purpose man can wish. In like manner biology can take the units nature has given us in plants and animals and build them into combinations far superior to those we now have. Out of anything that can be cross-pollinated or cross-bred new kinds can come. There are almost limitless possibilities in animal and plant breeding, and the field is so wide and so rich that the workers now in it cannot make more than a beginning at cultivating it. Let us consider a few breeding projects of a type that might be carried out.

Over much of our country insect and fungous pests have practically destroyed home orchards and dooryard fruits. Yet there are peaches that are immune to rot, grapes resistant to mildew, pears that do not blight, and wild plums that still produce their fruit. Should not someone be working to give us a set of home fruits that without constant spraying will resist insects and disease? Practically nothing has been done in this great field.

The apple does not do well in our Southern lowlands, but wild crab apples grow there. Might it not be possible to secure hybrids with these crabs that would move the apple belt south, just as Professor Hansen moved it north?

The almond is of the peach family and the part we eat corresponds to the kernel of the peach seed. There are hard-shelled

almonds that are perfectly hardy at 25° below zero. They have beautiful blossoms in early spring and are grown as ornamental trees. Might not the soft-shelled kinds be crossed with them and the hardiness and edible kernels be combined?

The pecan hybridizes with the hickory. Could it not be moved north? There are English walnut trees over our Eastern states, but most of them will not fertilize themselves. Could not self-fertile kinds or varieties that will cross-fertilize each other be found, so that these trees will bear nuts as well as leaves?

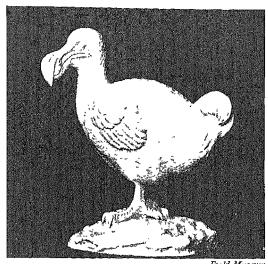
The filberts of England and France winterkill in our Northern states, but there are filberts that grow through Prussia and western Russia and our own wild hazels endure cold. Should not these hardy kinds be hybridized and varieties produced that will be suitable for planting about our Northern farm homes?

Some varieties of Japanese persimmons have fruit the size of a teacup. They flourish in our Gulf states. This persimmon is a good fruit. Should it not be hybridized with our native persimmons and brought north?

Should not someone be trying to hybridize some of the hundreds of kinds of wild figs with the edible ones to get roots that are resistant to nematodes? Could not much be done to secure a greater variety of perennial food-producing plants that would without annual plantings give their crops each year?

If our country were divided into areas 50 miles square, every square would need special plants to fit special conditions of soil and climate that are found in it. At present we have whole counties and even states and groups of states that lack field, garden, and orchard plants exactly suited to them, and the most efficient plant we have (corn) uses in food building less than 1 per cent of the energy the sun pours down on it. Our animals likewise need to be specialized and improved. We are carrying on vast numbers of activities far less useful than the improvement of our plants and animals, and if the funds devoted to this purpose were increased a hundredfold our nation would be greatly enriched. We know no limit to the improvements possible in our cultivated plants and domestic animals.

Caesar wrote that the urus (extinct ancestor of the cattle of Europe) was "the size of an elephant." Skulls of it are yet found in Europe and they indicate that it was much larger than modern cattle. It would be interesting and perhaps very profitable if we had the genes of the urus to combine with those of cattle from various parts of the world. Scattered over the earth are



The dodo, which was exterminated only about 250 years ago. It was a dove that weighed 70 pounds. Possibly if we had its genes today we could produce pigeons of giant size.

scores of kinds of sheep, goats, cattle, and relatives of our domestic animals. No one knows what could be built of the genes their chromosomes contain. The dodo was of the pigeon family and weighed 70 pounds. It has been completely exterminated, but doves the size of hens are still to be found in the tropical islands of the Far East. Possibly our domestic birds could be improved by the infusion of wild genes. One of the reasons for conserving wild life is that if we allow species to be exterminated, genes that some day might have been used in improving our cultivated plants and domestic animals may be lost.

As clay is plastic in the sculptor's hands, so is protoplasm yielding to the breeder's will. The combinations of its elements are not fixed. Its forms are not final. You might find an interesting and highly useful career in creating new and improved plant and animal kinds.

PROBLEM FIVE

How Are Farm Plants and Animals Bred to Secure Uniformity and Vigor?

Two highly desirable qualities in farm plants and animals are uniformity and vigor. When a farmer raises a flock of chickens or sheep he wants them to be uniform in type — not of all sizes and colors. He wants them to have vigor — to be healthy, to grow rapidly, to be highly productive. He wants all the individuals to be of a uniformly high excellence. A breed or variety that produces some superior individuals and others that are inferior or different is not satisfactory. How can the desired uniform excellence be achieved?

The production of superior plants and animals for agriculture is a strictly scientific procedure. For an appreciation of the methods used an understanding of certain biological facts and ideas that we have not yet considered is required.

Hybrid vigor. A cross between a lion and a tiger is larger than either of its parents. First-generation crosses between some breeds of swine or breeds of chickens are more vigorous than either of the parent breeds. Hybrid walnuts and poplars (for paper making) have been bred that grow faster than either of the parent species. In some cases, when different strains or species are crossed the hybrids have unusual vigor. Not all crosses give this vigor; some hybrids are inferior to both parents. Whether any particular cross will give increased vigor can be learned only by trial.

What is the explanation of hybrid vigor? Only a theoretical answer can be given. We know that sometimes hybrids have special vigor, but we cannot yet see deep enough into the genes to give an assured explanation of its origin.

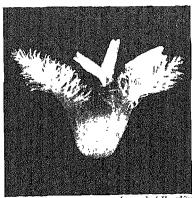
Suggested explanations. We could explain hybrid vigor by supposing that in the hybrid the two sets of chromosomes together supply an unusually full equipment of desirable genes. If one set lacks a gene or has an inferior one the other is able to make good the deficiency. Intermarrying between close relatives

in human beings is opposed on the ground that if there is any weakness in the stock it is likely to come out. If parents are related the two sets of chromosomes in the offspring are likely to have the same inferior genes or lack the desirable ones, and thus the defect will appear. Close inbreeding in animals often weakens the stock, and this weakening is attributed to matching up chromosomes that are defective in the same places. In sets of chromosomes from unrelated parents the weaknesses in one set may be made good by sound genes in the other. If two sets of chromosomes supplement each other unusually well in desirable characters, there will result hybrid vigor and a good cross.

Another explanation of hybrid vigor is that each of the parental sets of chromosomes furnishes genes that separately have no effect but that together raise the vigor or size of the offspring. In any case, whether or not these explanations are correct, there is such a thing as first-generation hybrid vigor, and it is taken advantage of in plant and animal production (page 263).

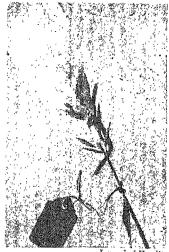
Pure-line plants. Suppose you plant a single bean of an

established variety. The plant grows and blossoms. Since beans are self-pollinated, your plant pollinates itself and produces seed. You save the seed and plant a row of beans in the garden. All the young beans are from the same single parent plant and you will find them remarkably uniform. The two sets of genes that come together in fertilization in the bean come from the same parent plant; there is no mixing in of outside protoplasm when an egg is fertilized and a young plant started. The sperms and eggs are all practically the same.



Journal of Heredity

The flower of an oat plant. The feathery organs are the pistils. The three stamens are in the center. The stamens wave about and rub the pollen on the pistil so that usually the flowers are self-pollinated.



Journal of Heredity

In the oat head shown here, the stamens were removed before the pollen was mature and the pistils cross-pollinated. The flowers were then covered to prevent other pollen from reaching the pistils.

In the offspring of such self-pollinated plants of established varieties there is little variation. Each individual plant represents only one line of protoplasm and it hands this on, unmixed with other protoplasm, to its offspring. The offspring of such a plant all closely resemble each other; they all have the same protoplasm; and they are said to be a pure line. A pure line is defined as "the descendants of a single organism, not itself a hybrid, that propagate themselves exclusively by self-fertilization."

Tomatoes, peas, wheat, grasses, and most clovers and other legumes are selfpollinated. In nature they form pure lines, although this is not always apparent because in the fields many lines may grow mixed together. One of the ways of

getting uniform excellence in these plants is to select a particular individual plant of superior vigor or productiveness, multiply the seed from it, and thus secure a strain that is a single pure line. The yields of pastures were increased 20 per cent in five years merely by selection of the best strains present among the grasses. Among self-pollinated plants, once a superior pure-line plant is found it will do its own breeding and keep the line pure. Notice the uniformity of the plants in a row of beans or peas.

Plant populations. The genetic condition in corn is very different from that in self-pollinated plants. If you go through a field of ordinary corn you will find big stalks and small ones; stalks with heavy ears and others with only nubbins or even no ears; stalks that go down before the wind and others that stand sturdily erect. In a cornfield there is great variation among the plants. One plant breeder selected 127 varieties from the progeny of a single ear.

A field of corn as it is ordinarily grown is what geneticists call a population and not a pure line. The individual plants vary because the corn is cross-pollinated and the different plants have genes from many different sources and in different combinations. Every plant is a hybrid; their parents have been hybrids for generations before them. Some of the plants are good and some of them are of little worth. A problem of the corn breeder is to develop the uniformity that is found in self-pollinated plants. He wants a uniform race of corn that will produce a full ear on each stalk.

Pure-line corn. A corn breeder develops a pure line by pollinating the ear with pollen from the tassel of the same stalk and then covering the ear to keep out foreign pollen. He plants the seed and gets many varieties; from these he selects the best plants and self-pollinates them. He continues doing this and in

time he gets a strain in which there is little variation. As in naturally self-pollinated plants. all the plants within a strain are practically This means that alike. the genes in each seed are the same; a pure line has been developed. The corn breeder produces a number of these pure lines. By selfpollination of the corn he develops pure lines, as peas and beans develop pure lines of themselves.

How pure-line hybrid corns are produced.

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SINGLE-CROSS PLANT (BXA)

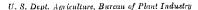
FIRST YEAR

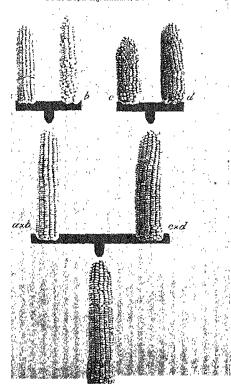
U. S. Dept. Agriculture

SINGLE-CROSS PLANT (CXD)

But while the corn breeder gets uniformity in his plants by producing pure lines he is likely to lose vigor and productiveness. Corn is one of the plants that tend to "run out" unless crosspollinated. Pure lines of corn are not vigorous and some of them are decidedly weak. The breeder must take an additional step to add vigor to the uniformity he has secured in his pure lines.

Pure-line hybrids. After the breeder has established his pure lines, he tries out crosses between different lines. Many of the hybrids will be failures, but he may find some crosses that give highly superior plants. The plants may have pronounced hybrid vigor. They will be uniform because each parent represents a pure line. If a breeder finds such a superior hybrid he multiplies the pure lines that were crossed to give it and produces the hybrid seed in quantity. He can do this by planting side by side rows of the two pure lines and cutting off the tassels of one

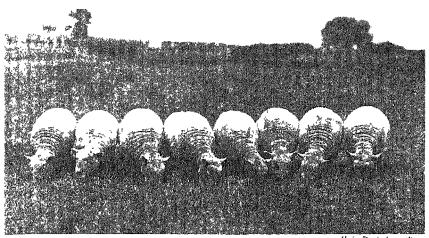




kind. Then all the seed from the plants which have been detasseled will produce hybrid plants.

Much of the corn grown in our country is produced from pure-line hybrid seed. These hybrids outyield all other corn; they often increase acre yields from 5 to 25 bushels; practically all prizes for high corn yields are won by them. Sometimes seed is used that is a cross between two pure-line hybrids—a combination of the protoplasm of four pure lines.

Second-generation hybrid corn combining four pure lines.



U 5 Dept Agriculture

Umformity in pure-bred Shropshire sheep Pure-bred animals represent lines into which many desirable genes have been gathered and from which undesirable genes have been weeded out.

Pure-bred animals. A general method long used in trying to obtain uniform excellence in domestic animals has been the building up of pure breeds and strains. From these breeds and strains the undesirable individuals are eliminated. The best individuals are chosen as breeders; no outside blood is brought in. In time a line is built up, the individual members of which are more or less related in blood and tend to uniformity.

A pure line cannot be produced in our domestic animals as in self-pollinated plants. Yet it can be approximated. Suppose the eggs of a hen are set and the chicks hatched. Each carries 50 per cent of the blood of the hen. Then suppose one of the cockerels is mated to the mother hen. A brood of chicks is produced that carries 75 per cent of the blood of the hen. If one of these cockerels is mated to the original hen we have offspring with 87½ per cent of her blood; and if breeding is carried farther in this way we come nearer and nearer to the 100 per cent.

In concentrating a blood line a breeder would probably use brother-and-sister or cousin matings and would not carry inbreeding so far as we have indicated. However, by breeding relatives together and selecting offspring resembling one of the original parents, an animal line that is in a degree a pure line can be established. Practically all high-bred animals are to an extent

inbred. When animals are inbred there is always danger that the blood will become weak. Breeders show their skill by mating animals of sufficiently distant relationships to insure that the vitality of the line will not be lost.

Hybrids in domestic animals. Crosses between certain breeds of animals and between particular strains within a breed may give good results. The parent breeds or strains are near enough to pure lines for the offspring to be uniform. Also the hybridization may give increased vigor. Most of the pork marketed in the United States is produced by hybrid hogs. Millions of hybrid chickens are grown each year. When lambs are raised to be sold for meat, cross-breeding often is practiced.

Formerly it was generally taken for granted that pure-bred animals are superior to hybrids. A dog that is a mixture of many breeds is called a mongrel and we speak of cattle that are of no one breed as scrubs. General recognition of the fact that the uniformity of pure-line plants and pure-bred animals can be combined with the vigor of first-generation hybrids is recent in the breeding world. In the scientific hybridization of plants and animals we have made a great breeding advance.

Securing uniformity in hybrids. Pure-line plants and pure-bred animals are uniform. They are inbred and the individuals are similar because all the germ cells tend to be alike. When two such strains are crossed there is uniformity in the hybrids also. Two and two always make four, and when uniform pairs of germ cells are mated they give uniform combinations. Some of the first-cross corn hybrids have a uniformity that is truly remarkable and some of the first-cross farm-animal hybrids are as uniform as any pure breed.

The disadvantage of unplanned and unsystematic hybridizing is the undependability of the results. The offspring may be good, they may be bad, as we see in a field of corn grown from ordinary seed. Hybridizing pure lines and particular breeds and strains takes the chance out of the crossing. The cross has been tried and the breeder knows what he will get.

Hybrids unsuited for breeding stock. Hybrid plants and animals are not suited for breeding purposes. The sperms or eggs produced by a hybrid individual differ in their chromosomes. Among the offspring there will be throwbacks and individuals that have genes in new combinations. To produce uniform hybrids with the vigor that comes with a first-line cross, it is necessary to use pure-line or pure-bred parents. The corn breeder keeps his pure lines running and each year produces his hybrid seed from them. Pure-bred hybrids in animals can be produced only by crossing pure-bred strains. One of the mistakes often made is in keeping for breeding stock hybrids that are themselves excellent individuals. When this is done the offspring becomes a population of mixed types and not a uniform group.

Two methods are generally employed to secure uniformity and vigor in farm plants and animals. The first is to build up inbred strains by continuous selection for the desired qualities. Breeds of animals and varieties of many crop plants (wheat, oats, tomatoes) are established in this way. The second method is to cross pure strains that in themselves may or may not have vigor but which are known in tested hybrid combinations to give offspring of high uniformity and productivity. To create new varieties and breeds, other methods are used. Hybridizations to unite genes in new combinations, and preserving the offspring of favorable chance mutations, are standard practices among those whose work is to mold protoplasm into new forms.

PROBLEM SIX

What Applications of Our Knowledge of Heredity May We Make in Human Society?

Homo sapiens in the eyes of nature is just an animal. He is given chromosomes and genes, and these operate under the ordinary laws of heredity. He has dominant and recessive characters, normal and defective genes. From the standpoint of a scientific study of heredity there is no particular reason for giving special attention to man; but since we are always of particular interest to ourselves, a few topics related to the heredity of man will be considered in this problem.

Human heredity mixed. The first point we need to understand is that in a civilized society there is great diversity among individuals because all the offspring are preserved and In domestic animals and cultivated plants only cared for. selected individuals are kept for breeding stock. Among wild species natural selection exerts its influence to eliminate the weak Among human beings as we know them, neither natural selection nor the artificial selection of a breeder is at work. The genes of every sort are thrown into the makeup of the next generation, with the result that there is variation among men such as we find in no other species. In mentality the range is from idiocy to genius. In instincts there is variation from the most destructive to the highly altruistic. In health and physical vigor the differences are such as are not found in other animal forms.

To a degree the preference of like for like makes for assortive mating in human society, but the heredity of the average person is extremely mixed. High intelligence may mate with low. Persons with musical or artistic gifts may marry those who lack these gifts. Good character may be joined with bad and high physical vigor with poor health. The average person has in his cells a great mixture of genes, some of them good and some bad.

Nature and nurture. A man may have become the head of a great industrial organization, the governor of a state, a uni-

versity professor, a poet, a scientific investigator, or the President of the United States. What accounts for his success? Is it his natural abilities — the genes that nature endowed him with? Or is it his opportunities for education and his meeting with people who help him on the way? Are we unskilled workmen, skilled workmen, tenant farmers, landowners, physicians, engineers, teachers, writers, industrious workers, loafers, successes or failures, because of what we are or because of our opportunities and environments? Doubtless both natural ability and opportunity contribute to success, but if we wish to find out how important each is we must find some scientific way of determining the part that it plays.

A generation ago Francis Galton in England made a study of men who had come to prominence in Great Britain. He found that many of them were members of the nobility and of families of wealth and influence, and that others had come into prominence and power out of complete obscurity. Even back in the times when the king and the nobility dominated everything, men were constantly moving up and being made noblemen. Galton's studies led him to believe that in a country with opportunities for education and advancement as open as they were in the England of his day inheritance is much more important than environment. He writes: "There is no escape from the conclusion that nature prevails enormously over nurture when the differences of nurture do not exceed what is commonly to be found among persons of the same rank in society and in the same country."

Nature and nurture in identical twins. It is possible to study in a more precise way than Galton did the relative importance of nature and nurture in the development of the human personality. The members of most pairs of twins come from different eggs. The eggs are fertilized by different sperms. Each twin is wrapped in its own placenta, and the members of the pair are not related any more closely than brothers and sisters born at different times.

There is, however, an occasional pair of human twins that

come from the same egg. The two halves of the egg separate when the egg is in the two-celled stage, and each half makes a complete individual. Such twins are both wrapped in the same placenta. They are always of the same sex. They often look so much alike that only members of their own families can tell them apart. They are called identical twins, and they ought to be much alike because they both come from the same fertilized egg and they have identical sets of chromosomes in their cells.

Usually such twins are very similar. Their intelligence is about the same. If one is lazy the other is lazy. They like the same foods and engage in the same sports. Their handwritings are similar and they tend to have the same abilities in music and in drawing. In Germany the records of thirteen pairs of identical twins, of whom one of the pair was in prison, were investigated. In ten out of the thirteen pairs the other member had been in prison also, and for similar crimes. The members of each pair not only resembled each other in their physical characteristics but in

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their conduct as well.

Now suppose that identical twins were separated in childhood and brought up under different influences. After they grew up would they still be alike, or would the different environments shape them into different kinds of persons? Would nature or nurture prevail? A study of a considerable number of pairs brought up in different homes and under different conditions has been made. More difference is found in them than in twins

Identical twins.

brought up together, but still the members of the pair are greatly alike. You may read about these investigations in books on human heredity. The general feeling among geneticists is that individual human beings with anything like equal opportunities differ from each other more on account of their genes than on account of their environments.

However, the argument whether good heredity or good environment is the more important is futile, since both are necessary. A person equipped with the finest heredity in the world could accomplish little if he were brought up and kept on an oceanic island apart from the knowledge and ideas of other men. And the finest conceivable environment could not change a person with a low-grade inheritance into a wise and great man or woman. Heredity supplies our native capacities; environment determines to a large extent how fully these capacities will be developed. It requires both good seed and good soil to produce an abundant crop of corn.

Are acquired characters inherited? Suppose a man spends his life as a bookkeeper. Will his children be any better in arithmetic than they would have been if the man had run a filling station? Suppose a young man becomes a great marathon runner. Will his boys have any more enduring legs because of their father's racing? Probably not. Only natural qualities seem to be passed on to another generation. "A wooden head is inherited, but a wooden leg is not." A simple biological way of looking at the question of inheritance of acquired characters is as follows:

When the cells of the body become specialized, some become muscle cells, some nerve cells, some gland cells, and so on. A few — the reproductive cells — do not become specialized. They stay young and keep on growing and dividing. At times one of these cells is used to start a new individual. It multiplies, the resulting cells again specialize into the various body tissues, and again a few of the cells are saved out for youth and reproduction. On and on through the generations the process is repeated. There are two classes of cells, the body cells and the reproductive cells.

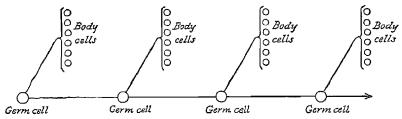


Diagram to illustrate the relation of the germ plasm and the body cells. The germ plasm is passed on from generation to generation, while the life of the body cells is for only one generation.

The body cells live one generation and die. The reproductive cells go on and on and on. The "immortality of the germ plasm" is no idle phrase.

When we educate or train a person, which cells are affected? The nerve and muscle cells — and these are not passed on. The reproductive cells that are passed on can carry with them only their natural qualities. They transmit not characters, but determiners of future characters. The training and education are left behind at each generation in the body cells that receive them. There is simply no mechanism for transmitting them. One of the encouraging things about the human organism is that it can be so easily improved by training. One of the discouraging things is that with each generation the training must all be done again.

But the body is the seat of complex chemical reactions, and chemicals of many kinds are in the blood. Our ductless glands, our muscles when we exercise, doubtless our brain cells when we think, release chemicals. Could these chemicals not influence the reproductive cells, change them so that their genes would express themselves in new ways? Possibly they might. We have no evidence that they do. We do not know any way to improve the genes of these cells. At present it is best to go on the assumption that natural qualities are inherited and that those who are naturally the best will transmit the best genes to their offspring.

Eugenics, or improving the human stock. If you plant a row of radishes in the garden, some will grow quickly and make good roots. Some will be feeble and tardy in growth and may never make radishes fit for the table. If you should pull out

the good ones to give the poor weak ones room and then should save the seed for the next crop from the weak ones, that would not be eugenics (u-jĕn'ĭks). If you pulled out the inferior ones and saved seed from the best, that would be eugenics. The word eugenic means "well-born." It carries the idea of breeding from the best.

In animals the feeble and defective are eliminated by natural selection or by the selection of the breeder. In civilized society we nurse and carry the undesirables along until we have an enormous population of feeble-minded, criminal, shiftless, and insane. The eugenist would eliminate these from the human breeding stock. This is the negative side of a eugenics program. The positive part of the program is the arranging of a social order that will allow and encourage those of high abilities and desirable character to marry early and raise large families.

As you take your place as a citizen you will be called on to consider one social and political measure after another. You should scan each measure from the point of view of whether it will in the end give us a citizenry with better or poorer genes. The welfare of a people in the end is determined by what the people are.

A PRACTICAL GENETICIST

"The inventor, the chemist, the electrical genius have all contributed untold wealth and happiness to the world, and their work still goes forward. But I assert that the most priceless legacy which man has ever received from any source in the study of Nature lies in learning to guide the creative forces of plant life into new and useful channels." LUTHER BURBANK

One type of scientist works merely to find out things. A second kind finds his primary interest in applying his science to



Luther Burbank (1849–1926), a pioneer of renown in the field of plant breeding. His genius and activity gave to the world many new kinds of fruits and flowers. (Photograph from Burbank's Partner with Nature, D. Appleton-Century Company, Inc.)

useful purposes. Among the names of the practical workers in the field of heredity in our own country, that of Luther Burbank must be ranked high.

Born a farm boy, he began his manhood career with only an elementary schooleducation. without money and resources. He was forced to make his own living. which he did by selling nursery stock and as a seedsman. before others had awakened to the possibilities of plant breeding he had the vision to see them, and before Mendel's work was known he was producing better plants by combining the superior qualities of several kinds in one. Read of the life and work of this man who expressed in the sentences quoted at the top of this page his faith in the possibilities of plant breeding and who proved his faith by sending out year after year a steady flow of splendid new fruits and flowers.

UNIT COMPREHENSION TEST

- A. What is genetics? Who was Gregor Mendel? Give an account of his experiments. Give two fundamental discoveries that Mendel made. What results did Mendel get with his second-generation hybrids? What are throwbacks? What explanation can be given for their appearance? Explain how Mendel's discoveries can be used in plant and animal breeding.
- B. Define: chromatin; nucleoplasm; chromosome; reduction division; gene. What happens to a chromosome in ordinary cell division? What is the origin of the chromosomes in the cells of an organism? Why does not the number of chromosomes increase from generation to generation? Explain what is meant when we speak of two sets of chromosomes and two sets of genes. Explain the 1:2:1 ratio that Mendel found in the F₂ generation of his peas. What is meant by a sport or mutant? Give an example.
- C. Give three possible explanations of intermediate hybrids. Mention examples to illustrate each. What is meant by cumulative genes? Give examples. Explain inheritance of sex in Protenor; in human beings. Define and explain linkage of characters; crossing over. Explain how defects can be covered up in inheritance. Discuss vegetative mutations ("bud sports"). How is colchicine used in plant breeding and what effect has it?
- D. Give an account of the work of Professor Hansen. Tell about some new crops for the West; for the Southeast. Mention other plant-breeding results. Tell of some of the work that is being done in animal breeding. Give examples of opportunities open to plant and animal breeders.
- E. Mention two qualities desired in farm animals and cultivated plants. What explanations of hybrid vigor are offered? Define: pure line; population. How are pure-line plants produced? Mention some crops in which pure-line seed is used. What is a pure-line hybrid? Why are they produced? What is meant by single-cross and double-cross seed corn? How are pure-bred animals produced? What advantage is there in them? In the breeding of what farm animals is hybridization often practiced? Explain why hybrids of pure-line plants and pure-bred animals may be as uniform as their parents. Why are hybrids not suitable for breeding stock?
- F. Why is there great variation among a human population? What is meant by "nature and nurture"? What is meant by "identical twins"? Why are they especially good material for the study of the relative importance of heredity and environment? What conclusion is indicated by a study of them? Are acquired characters inherited? Explain. What is eugenics? Illustrate. Tell something of Luther Burbank.

SUGGESTED ACTIVITIES AND APPLICATIONS

1. Examine cells in a prepared section of a root tip. With a high-power microscope study the nucleus and note the chromatin network. The dark round body usually seen in a nucleus is the *nucleolus*. It is composed of chromatin.

Look for cells in division and examine the chromosomes. Note short pairs of cells, indicating recent division, and spreading out of

the chromosomes into a network again.

2. In your notebook make diagrams showing how the number of chromosomes is reduced when sperms are formed.

3. Secure a quantity of white and of yellow corn with grains of about equal size and shape. (Beans of approximately the same size but of different colors may be used. If desired, white corn or beans alone may be used by coloring one lot red, yellow, or blue.)

Working in pairs or groups, let the pupils count out 1000 grains of each color and mix them thoroughly in a bag or other container. Draw the corn grains (or beans) from the container in pairs, keeping a record of the times the same and mixed colors are drawn. Is the ratio approximately 1:2:1?

The ratio can be tested by flipping two coins in the air and keeping a record of the number of times they light both heads, both tails,

and heads and tails.

4. Corn breeders would rather produce and sell for seed F_2 generation (double-cross) corn like that shown on page 690 than the F_1 generation (single-cross). Why should this be true?

5. Suppose 200 married couples are divided into two groups of 100 couples each. The couples of the first group have two children each and those of the second group five children each. There is in the two groups of people what is called a differential birth rate.

Counting three generations to a century and assuming that all children live and have as many children as their parents, how many descendants will the first 100 couples have at the end of 200 years? How many descendants will the second 100 couples have?

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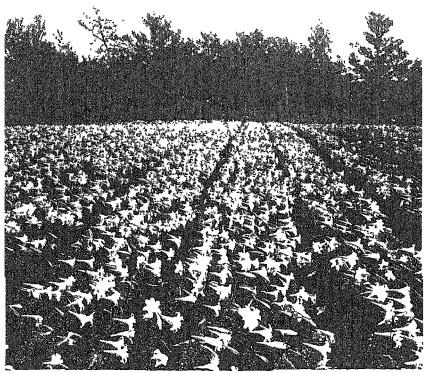
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Brown Brothers

UNIT 16 BEHAVIOR

Plants and the lower animals are governed by stimuli from without and by hereditary influences from within. In the higher animals, and especially in man, intelligence is an added factor in conduct control.

"Something guides the lower animals, but it is not thought; something restrains them, but it is not judgment. They are active without industry; they are skilled without practice; they are wise without knowledge. What they do does not involve reflection or memory."

JOHN BURROUGHS

THE IMPORTANCE OF BEHAVIOR

QUESTION FOR CLASS DISCUSSION

Both the llama and the camel of the Old World spit on anyone with whom they are displeased. How can this similarity of behavior be accounted for?

ADAPTATION of action in a living thing is as necessary as adaptation of structure. The roots of plants would be of no use if they did not turn downward and grow into the earth. Our sweat glands would be worse than useless if they flooded the skin with moisture when the body was cold and ceased working when it became hot. A bee's wings and tongue would be of no value to it if the owner did not use them to go out and gather nectar from the flowers. A squirrel might as well be without claws if it did not go up a tree with them when a dog or a fox comes. After all the parts necessary to make a plant or animal fitted for a certain environment have been assembled, it is necessary for each of these parts and for the organism as a whole to act in appropriate ways. How is the behavior of living things controlled? What causes organisms to do what they do?

We do not promise to answer this question very satisfactorily, for understanding of behavior is decades behind our knowledge of bones and muscles and the functions of organs like the kidneys and liver, whose workings can be investigated by means of chemistry. Nevertheless, "it is in the deepest darkness that a little illumination reveals most," and in science the greatest fascination is in the unknown. We shall, therefore, in this unit move out into a no man's land where scientific workers point out to each other the inadequacy of the ideas that are advanced. Since the actions of all animals except the simplest ones are controlled through the nervous system, we shall include in our unit a more detailed study of the workings of this system, especially in the higher vertebrates.

The importance to us of the subject of behavior is very great. It is what people do that makes the world a good or a bad place in which to live. The great need of the world today is a set of people whose behavior is worthy of their mental and scientific advancement. The theme song of biology is adjustment to life conditions, and the problem facing man today is whether or not he is going to be able to adjust himself to the world that science has prepared for him. Scientific knowledge has put into man's hands enormous powers, and often these are used without conscience or intelligence. We need additional scientific knowledge to guide us in fitting ourselves into the new conditions that we ourselves have created and to meet the rapid changes in conditions that will surely continue to come. Even a little knowledge of how to get Homo sapiens into a more sane and scientific course of behavior would be of great worth, for man himself is the problem of problems of mankind.

Problems in Unit 16

- 1 How is the behavior of plants and of simple animals controlled?
- 2 Is the behavior of higher animals controlled by anything besides the intelligence?
- 3 How does the nervous system operate in controlling the body?
- 4 Do the emotions have an important effect on behavior?
- 5 What other factors are important in the control of human behavior?





When this begonia plant was placed in a window, its leaves turned to the light. The response to the light stimulus placed the leaves in a favorable position for carrying on their food-making work.

PROBLEM ONE

How Is the Behavior of Plants and of Simple Animals Controlled?

Examine with a microscope a drop of water that is filled with paramecia and other protozoa. A busy scene is before you. The little animals are all rushing about as if each one were hurrying to catch a train. There is no hesitation. Watching one of them, you would think it was intently following a planned way.

What makes these little animals keep moving? They have no brains or eyes or ears. What guides them in the directions that they take? In part, at least, they are governed by stimuli from without. Protoplasm is so built that it is affected by outside influences and responds to them.

Plant responses to external stimuli. Germinate a pea in moist sawdust or sand until the root of the young plant has turned down and the stem is pushing up. Then place a strip of cork or a stick of wood so that it will stand upright in a vessel of moist air and pin the bean seedling to the wood, with the root and stem pointing horizontally.

The root bends and turns down and the stem bends and turns up. The root is *positively geotropic* (je'o-trop'ik; Greek *ge*, earth, + *tropos*, a turning) and the stem is *negatively geotropic*. The one turns toward gravity and the other away from it.

Set a plant in a window and the leaves turn to the light. They are positively phototropic (Greek photos, light, + tropos, a turning). On a hot day stroke gently with a pencil or a small stick a young tendril of a squash or grapevine on one side and in a short time it will begin to curl. It is positively thigmotropic (Greek thigma, touch, + tropos, a turning); if it touches something it bends toward it. Roots grow toward moisture or fertilizers in the soil. This is positive chemotropism (ke-motropiz'm), a turning toward a chemical.

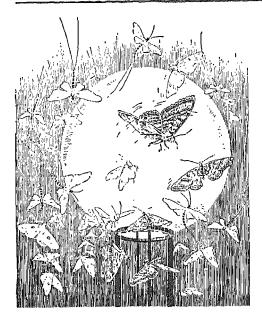
Animal responses to external stimuli. Animals too are influenced by outside substances and forces. If a slender hydroid is drawn through a coarse wire screen, with its basal part

left sticking in a mesh, and then the screen is immersed in water so that the hydroid is base up, the animal will turn and come up through another opening in the screen until the mouth end is up. If the screen is reversed the animal will again turn and come up, weaving itself back and forth through the screen. The mouth end, like the stem of a plant, is negatively geotropic and the base end positively geotropic.



The hydroid was made to weave itself through the screen by turning the screen over from time to time. The animal responds to gravity by turning the mouth end up. (After Loeb.)

Some species of young caterpillars are negatively geotropic, and as soon as they hatch on the trunk of a tree they start up it. This ascent ordinarily brings them to where the leaves are, but if one goes up a dead branch the negative geotropism holds it there until it dies. Houseflies are positively phototropic and earthworms and practically all the animals that live under boards and stones are negatively phototropic. The fish that ascend rivers to spawn are in the breeding



Injurious response of insects to light. The tropistic reactions of organisms are on the whole favorable to them, but they are blind and may lead to the destruction of the organism.

minerals, and perhaps other factors. A tropism does not act in a world from which all other influences have been removed.

5. The tropistic responses an organism makes must be on the whole favorable to it. If this were not the case the organism could not continue to exist. Just as the digestive tract of an animal must be adapted to the food it eats, so must the responses that plants and animals make be adapted to their environments and wavs of living. Inside an

organism there is an inherited something that causes it to respond as it does to the stimuli that fall upon it from the outside world. The organisms that inherit that which causes them to respond in favorable ways are the ones that survive.

Yet tropistic responses are blind and inflexible, and without intelligence to modify and guide them they may lead to the destruction of the organism. The illustration above shows an injurious response that is familiar to all.

Mechanistic conception of behavior. A drop of water on a piece of clean glass spreads out flat. On a greasy surface it rounds up. On a piece of soft paper it at once enters into the paper; on cellophane it does not penetrate. What happens to it is explained by the physicist and the physical chemist in terms of surface tension, capillarity, imbibition, and other forces

that play on it. Everyone thinks of the water as being acted on rather than as itself acting.

It is easy to think of a one-celled animal as a tiny droplet of protoplasm whose behavior must be explained in the same way as the action of a drop of water. A euglena, ameba, or paramecium responds to heat, to light, or to chemicals. It turns toward or away from stimuli that reach it from the outside. "The light is its will," wrote one scientist in a discussion of the phototropic reactions of a small organism. There is a school of biologists (called "mechanists") who regard plants and animals as mere chemical and physical machines and who believe that not only the behavior of living organisms but also all life processes and life itself will sometime be explained in physical and chemical terms.

On the other hand there are many biologists who feel that there must be something more in a living thing than physics and chemistry, as we know them, can account for. We cannot explain the beating of the water by the cilia of a paramecium in terms of physics and chemistry. We cannot explain why, when the animal strikes an obstacle, the cilia reverse and make it back up. A paramecium placed in a very narrow glass tube at first required 48 seconds to turn round, but after practice it learned to make the turn in 2 seconds. We have no explanation of such a learning process. Much less can we explain consciousness and the intelligent actions of higher animals in physical and chemical terms. That organisms do respond to external stimuli is a simple fact, but that behavior can be wholly explained in terms of these responses is not evident.

The scientific study of behavior is only of recent date and our knowledge of it is not yet in fundamental terms.



Hugh Spencer

Through the guidance of instinct the hen brought this family into the world. Through inherited wisdom she knows how to take care of them. The chicks will obey without training calls they have never before heard.

PROBLEM TWO

Is the Behavior of Higher Animals Controlled by Anything besides the Intelligence?

We can see that the behavior of a plant or of a very simple animal may be controlled, at least in part, by unconscious responses that it makes to outside stimuli. Is the behavior of the higher animals controlled in any such blind way, or do they act only through intelligence? The higher animals as well as the lower animals and the plants are guided in what they do by something besides their intellects. We say that they act by instinct, or that their actions are instinctive.

Definition of instinct. An instinct is an inherited something in an animal that causes it to perform certain unlearned acts without any reasoning about why it does so. We have no explanation at all of instincts and of how they cause the actions to be performed. All we know is that because of something within the animal it responds to the conditions in which it finds itself by doing certain particular things and that it is able to

perform the act without previous experience. We shall give a number of examples of instinctive responses to show their importance and complexity. Note how very specific and distinct some of them are. The differences in the natural behavior of different kinds of animals is mainly a difference in the instinctive responses they make.

Hen and chickens. A hen that as a chick has been hatched in an incubator, raised under an electric brooder, and kept entirely away from other hens will make a nest, fill it with eggs, and sit on them. She will turn the eggs in the nest from day to day with her beak, and when the chicks have hatched she will lead them forth and cluck to them to come along. If she finds food she will give a call that she herself never heard and the chicks, who never heard the call, will run to her. If she

sees a hawk she will utter another unlearned call, and although the chicks have never heard this sound before each one will sink to the ground and remain still. These are instinctive actions. Neither hen nor chicks learned to do these things or reasoned out how or why they do them.

Solifuge and scorpion. In the deserts of central Asia there are creatures like great, hairy spiders that are known as solifuges (sŏl'ĭ-fū-jes). There are also large black scorpions 5 or



Hugh Spencer

Without instruction in handicraft, this caddis-fly larva made for itself a protective case. It had no sand grains (see page 219), but it obeyed the instinct to provide itself with a covering and used sticks.

6 inches long. Both of these hunt over the desert at night and when they meet they battle each other to the death. The scorpion faces its foe with claws upraised and tail curved upward, ready to strike with its venomous sting. The solifuge shields itself behind its upraised hairy arms and circles the scorpion, watching for an opportunity to attack from the side or the rear.



Photograph by E R Warren, "Mammals of Colorado"

The pika, whose unconscious wisdom leads it to cure hay. It thus provides itself with a food supply for the long period of snow and cold.

All at once the solifuge makes a swift pounce. If it is successful it grips the scorpion's tail with its jaws. The scorpion struggles desperately, using its claws, but the solifuge pays no attention. The enemy's weapon is the javelin in its tail and the solifuge clings and chews until the power to use this is gone. When the scorpion has been deprived of its sting the solifuge can easily master it.

No one teaches the solifuge to attack the scorpion's tail.

Young solifuges have been reared without ever seeing a scorpion and yet they know how to do this. Neither do they learn by experience, for if a solifuge did not know the danger point of a scorpion its first fight would be its last. The solifuge has a specific race wisdom inherited by all members of the species from generation to generation. It is an inherited wisdom, unlearned and untaught.

The pika. In the Rocky Mountains from Colorado north there is a cheerful little animal called the pika (pī'ka). It is a close relative of the rabbit, but it belongs in a genus of its own, separate from the rabbits. Like the rabbits it has a small cerebrum and is not supposed to have much intelligence; but read the account that Dr. W. T. Hornaday gives of this little creature:

"It is very small and weak, but by its wits it lives in a country reeking with hungry bears, wolverines, and martens. The pika is so small and so weak that in the open he could not possibly dig down below the grizzly bear's ability to dig.

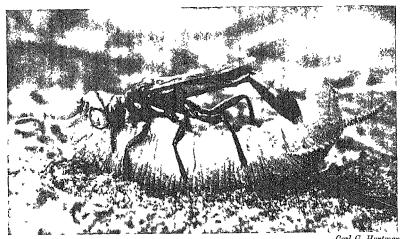
"And what does he do to save himself, and insure the survival of the fittest?

"He burrows down in the slide-rock that falls from the cliffs, where he is protected by a great bed of broken stone so thick that no predatory animal can dig through

it and catch him. There in those awful solitudes, enlivened only by the crack and rattle of falling slide-rock, the harsh cry of Clark's nutcracker, and the whistling wind sweeping over the storm-threshed summits and through the stunted cedar, the pika chooses to make his home. Over the slide-rock that protects him, the snows of the long and dreary winter pile up from six to ten feet deep, and lie unbroken for months. And how does the pika survive?

"When he is awake, he lives on hay, of his own making! "In September and October, and up to the arrival of the enveloping snow, he cuts plants of certain kinds to his liking, he places them in little piles atop of the rocks or fallen logs where the sun will strike them, and he leaves them there until they dry sufficiently to be stored without mildewing. Mr. Charles L. Smith declared that the pikas know enough to change their little hay piles as the day wears on, from shade to sunlight. The plants to be made into hay, usually about a foot in length, are cut at the edge of the slide-rock and are carried in and placed on flat-topped rocks around the mouth of the burrow. stems are laid together with fair evenness, and from start to finish the haymaking of the pika is conducted with admirable system and precision. When we saw and examined half a dozen of those curing hav piles, we felt inclined to take off our hats to that small animal which was making a perfectly successful struggle to hold its own against the winter rigors of the summits, and at the same time escape from its enemies."

We can hardly believe that the pika knows that winter is coming (it may never have seen a winter) and that it must put up a store of hay (it may never have seen hay). We could hardly think that it knows the hay will mold (it may never have seen mold) unless sufficiently dried, and so spreads its cut grass in the sun (it may never have seen grass dry in the sun). Without trying the experiment we may be sure that a young pika raised away from others would get ready for winter in the usual way. We feel sure that guided by instinct it would go through its summer preparation for the season of darkness and cold. We may



Carl G Hartman

A burrowing wasp and its prey. The wasp turns the caterpillar on its back and stings it in the ventral nerve cord. It digs a deep hole in the ground, drags the caterpillar to it, and buries it. Through something within it the wasp is guided through this series of complicated acts by which a supply of food is provided for its young.

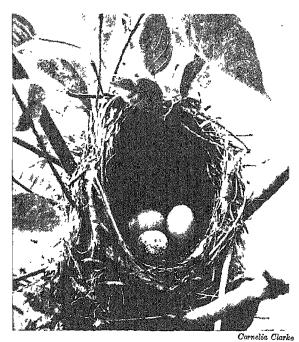
number of her eggs and then turns it loose. Within the eggs the fly larvae develop, and when the mosquito is biting a man, monkey, or other animal they wriggle out onto the skin of the victim and bore into it. Thus through complex and highly specialized instinctive acts, both on the part of the adult fly and of the larvae, the young of the fly reach the place of their development.

Characteristics of instinctive responses. It is important to distinguish between instinctive acts and those that are the result of intelligence or training. In the following paragraphs some of the characteristics of instinctive reponses will be pointed out.

1. An instinctive action is inherited and unlearned. A cat knows how to carry her kittens without being taught and a newborn kitten does not need to go to school to learn how to get its dinner. A spider can make its web without instruction and an oriole without teaching is able to build its nest. Instinctive acts can be carried through without practice and without under-

going the learning process. The ability to perform them is handed to the animal ready-made as a part of its inheritance. No one teaches a puppy to frisk and to wag its tail.

2. Instinctive actions are independent of intelligence. A bee does not plan a honeycomb with six-sided cells and a bird has in its mind no blueprint of a nest. These animals begin work and an innate blind some-



A cowbird's egg in a neighbor's nest. Instincts are blind and the cowbird takes advantage of this fact to get other birds to rear its young.

thing within guides their acts. Some animals of very low intelligence do by instinct some very wonderful things.

Instinct and intelligence in the animal kingdom are two peaks that push up independently. Both may and do exist in the same animal, but they are separate and should not be confused. Instinct is not intelligence and often instinctive acts are carried out in defiance of intelligence. An ancient philosopher wrote, "I see the better way and take the worse."

3. Instinctive actions under "natural" conditions are beneficial to the individual or the race. An instinctive act is directed to a purpose, even though the animal performs the act unconsciously and is ignorant of its purpose. Possibly "purpose" is not the right word to use in this connection, since to most persons it implies conscious individual intent in the act; but at least we can say that ordinarily an instinctive act is helpful to the animal or to its race, and when we watch an animal perform one it seems to us that it is doing what it does in order to have the benefits

that result from the act. The same may be said of tropistic responses. They are beneficial and seem to be for a purpose, but they are unplanned by the organism that is reacting. We do not believe that a root turns to moist soil *in order to* get water; it turns to moist soil *and* gets water. When an animal acts by instinct it has no end or purpose in view, but only those animals survive that instinctively act in a way that brings results favorable to them.

4. Instincts are inflexible in their operations and sometimes they lead to actions that are harmful. Instinct is a blind force in the grip of which an unintelligent animal must press on in a predetermined way. At times swarms of butterflies, under the urge of a migrating instinct that drives them to the northwest, ascend the slopes of the Himalayas and perish in the high fields of ice. Birds when captured and exposed to long hours of light started north instead of south when they were released in autumn. The little rat-like lemmings of the mountains and tundras of Norway sometimes start in droves to the west and continue their westward drive until they drown by thousands in the sea.

A broody hen will sit on stones, on a door knob, or in an empty nest. The emperor penguin, which incubates its egg by clasping the egg between its thighs and holding it against the body, will if the egg is destroyed try to incubate pieces of ice. Instincts are rigid and blind in their operations and by their very inflexibility they may lead an animal to useless actions or even drive it to its own complete destruction.

Changes in instincts. Instincts may change according to the age or physiologic condition of an animal. Like tropisms, they are not constant through the life of the organism. Birds have the mating and young-rearing instincts only in spring and early summer. Their migratory instincts are operative only in the spring and fall. A hen's broody instinct comes only at the end of a cycle of eggs. A cat with kittens will let a baby skunk sleep in the nest with her and nurse with the kittens, but if she has no kittens she will have nothing to do with any baby animal. Moreover, some instincts can be changed at once by injection

into the blood of hormones from some of the ductless glands. An injection of a substance (prolactin) from the pituitary gland will cause a hen to become broody and will make a rooster cluck. The migratory instincts of the birds change with the length of day.

Instincts are rigid while they last and many of them are enduring, but one must not think of an instinct as immutable. An animal's instincts change as the animal grows older; new instincts come into being and old ones tend to fade away.

Instincts and tropisms. Is an instinctive act, like a tropistic movement, always a response to an external stimulus? It is supposed to be. Many biologists are inclined to look on instincts as being much the same as tropisms except that they are more complex. A blowfly lays its eggs on meat where the young will have food, and the argument that the acts which result in its doing this are a series of responses to outside stimuli runs as follows: The odor of the meat attracts the fly. The fly is turned to the meat as a plant is turned to the light. When the fly arrives at the meat and alights on it, the muscles of the oviduct are set in action by some stimulus and the eggs are forced out.

In the same manner it is explained that when a bird is in the proper physiologic state, a suitable place for a nest stimulates it to bring a twig. A partly built nest calls for grass or hair for lining material. Eggs arouse the sitting response, and the appearance of babies sends the parents for bugs and worms. You can decide for yourself whether you consider such an explanation satisfactory. It seems a hazy and inadequate way of accounting for all the things that animals instinctively do.

Instincts and human behavior. Does man have instincts? Certainly.

"We want some things because we like them, We do some things because we're what we are."

Each person born into the world has a personality. As he grows, certain traits develop in him. He has a group of instincts that incline him to act in definite ways and are the primitive

T22 BEHAVIOR

rootstock of his desires. Jung, the student of subconscious psychology, has said "the mainsprings of human conduct are in the instincts." Mark Twain, who was a shrewd judge of human nature, said that the intelligence was given to man to invent reasons for the things he wants to do. Doubtless you at times have felt yourself impelled to follow a course of action your intellect told you was unwise.

Instincts not only have a direct effect on our actions but they have also an indirect one. To a marked extent the instincts of an animal determine the life it will lead and therefore the experiences it will have and what it will learn. In man the instincts of the individual have the say about what controls and customs he will accept, what habits he will form, and what advice from the intelligence he will accept. Parents provide for their young a training that is in accordance with their ideas of what is appropriate and right, but individuals among the young respond to the training differently. Out of the same environment — even out of the same home — one person will respond to one set of influences and another to a different set, so that one person comes out with one set of habits and manners and mental attitudes and another with a different set. This can be accounted for only by the assumption of natural differences in the two persons. inherited different genes and therefore have different instincts.

As you view the world of animal life above the simplest forms you will find that the activity in it is largely governed by instinct. In the higher animals intelligence is added to instinct but instinct is not lost. The higher animals have all that the lower animals have and something more. Human parents have instincts that cause them to care for their offspring. A little child instinctively runs to its parents when it is afraid. Human beings have mating instincts and instincts that cause them to seek association with other persons and to gather in groups. Down in the old lower brain there is something unconscious and unreasoned that helps direct our ways.

PROBLEM THREE

How Does the Nervous System Operate in Controlling the Body?

Each tissue in the body has been specialized for some particular work. The red blood cells are specialists in carrying oxygen and the muscle cells in contracting and causing movement. The nerve cells are the connectors of the different body parts and the coördinators, or regulators, of the body's activities. Out of the many organs and parts that compose the body the nervous system makes one whole. It is able to do this work because the nerve cells have specialized in *irritability* and *conductivity*. Let us illustrate what is meant by these terms.



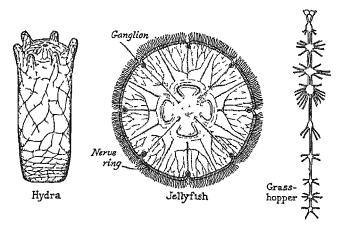
The stimulus starts an impulse in the leaf of the sensitive plant. The impulse travels downward and causes the leaflets to fold.

The sensitive plant. In the tropics there grows as a weed a small species of mimosa (Mimosa pudica) that is commonly known as a sensitive plant. Like all mimosas, it has fine-cut, compound leaves and it has the appearance of a tiny locust tree perhaps a foot in height. Cattle are fond of the delicate leaves, but if an animal begins to eat them and shakes the plant, all the leaflets fold up and the stems of the leaves droop. The plant then, instead of appearing as a mass of appetizing tender foliage, seems to be made up chiefly of stems. This plant is sometimes raised in greenhouses. For ten cents you can buy a packet of

seed from a seedsman and raise as many sensitive plants as you wish.

If you hold a match flame to the tip of a leaf of the sensitive plant, in a few moments the leaflets will fold up and the petiole of the leaf will sink down. The protoplasm of the leaf is *irritable*. It responds to a stimulus from the outside. The heat of the flame has an effect on it and causes it to do something. *Irritability is the capacity to respond to an outside stimulus*.

The flame is applied to the tip of the leaf. The response is at the bases of the leaflets and down at the base of the petiole. When the leaf is upright the cells are turgid at these points—tight with water, like well-filled little balloons—and by their firmness they hold the petiole erect and the leaflets in place. When the flame touches the leaflet something travels down to these cells that causes a sudden change in them. The water passes right out of them into the intercellular spaces, and the cells collapse and let the petiole and leaflets droop. The stimulus starts an impulse which is conducted through the protoplasm of the leaf to a point at some distance from where the flame is applied



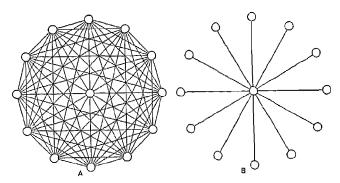
The network nervous system of the hydra, the ring nervous system of the jellyfish, and the linear (line) type of nervous system found in worms, arthropods, and vertebrates. One great function of the nervous system is to put all the body parts into connection with each other.

and there causes a response. As the term is applied to protoplasm, conductivity is the capacity to conduct or carry an impulse.

Nervous system as connector of body parts. Plants and sponges have no nervous systems. They respond slowly to stimuli and in them the impulse must work along through the ordinary cytoplasm from cell to cell. All the animals above the sponges have nervous systems, tissue that has specialized in irritability and conductivity. They have a set of cells that are expert in picking up stimuli and shooting impulses to the organ whose action is called for. In this way the many parts of the body are connected and each is made to respond at the right time and to the right degree.

In the hydra the nervous system is a simple network in which the branches of the neurons touch each other. In more complex animals the nerve cells are gathered in centers and the connections between the neurons are made in these centers. The illustration will make clear the advantage of the centralized plan. In a complex animal it would not be possible to connect all the different organs and parts in any orderly way except through a central system.

Neurons that connect other neurons in nerve centers are called



The diagram at the left shows the number of wires that would be required to connect directly each of twelve telephone stations with all the others. The diagram at the right shows the number of wires required when the connection is made through a central office. It is easy to understand the advantage of making nerve connections through a central system.

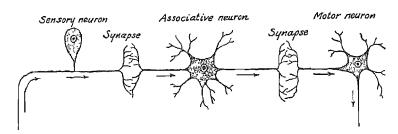


Diagram illustrating synaptic connections between neurons. The impulse travels only in one direction through a synapse.

associative neurons or adjustors. The places where the branches of neurons meet are called synapses (syn-ap'ses; singular, synapse). At the synapse a nerve impulse passes from one neuron to another. By the joining of their branches the nerve cells form a communication system through the body that is continuous and complete.

Nervous system as coordinator. The nervous system is a connector of the body parts, but it would be a mistake to think of it as a mere planless tangle of fibers through which impulses run aimlessly about. The nervous system of an animal such as the earthworm, bee, or frog may be aptly compared to a modern telephone system. There are incoming nerves that bring messages from the outside. There are outgoing nerves that carry messages to the muscles or other organs that should make the responses. There are nerve centers (brain and spinal cord) whose function it is to make the connections between the incoming and outgoing neurons, so that the impulses will reach the right places.

To appreciate the functions of the nervous system as a relayer and coördinator of impulses, an understanding of what happens in a *reflex act* is necessary. By a reflex act we mean an act caused by an impulse that starts in the *outer* ends of nerve fibers.

Example of reflex action. If you touch something hot the heat starts an impulse up the nerve from the finger. This goes into the spinal cord and there the impulse is directed into the nerves that go to the muscles that move the arm. The impulse comes back out of the cord and travels down to the arm muscles.

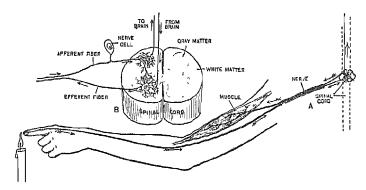


Diagram of the path of an impulse in a reflex action. The stimulus starts in the outer end of a nerve fiber.

When it reaches them they contract and jerk the finger away from the hot object. At the same time an impulse goes on up the spinal cord to the brain and causes a sensation of pain. It is not, however, the feeling of pain that causes the finger to be moved. The nerve impulse that comes in is relayed back to the muscles from the spinal cord before the sensory impulse has reached the brain.

The word "reflex" is from the Latin reflectere, to bend back. Applied to an action, it means one that is caused by a nerve impulse that is reflected or turned back. In a reflex action the impulse starts in the outer nerve ends and not in a nerve center. The brain or spinal cord does not originate the impulse, but reflects an impulse that came to it from the outside.

The path over which an impulse that causes a reflex act travels is called a *reflex arc*. In the simplest form in which we could think of such an arc it would consist of two neurons. There would be required an afferent neuron to bring the impulse in and an efferent neuron to carry the impulse back. Of course in reality things are much more complex than this. If someone should drop a piece of ice down your back scores of neurons would be stimulated to bring in impulses; hundreds, probably thousands, of associative neurons would be engaged in coördinating and directing the impulses to the neurons which connect with the muscle fibers that contract and effect the response.

Natural reflexes. If someone strikes at your face you will close your eyes. No one taught you to do this. It is a natural reflex. The moving image of the hand on the retina of the eye starts impulses to the brain and these are turned back to the muscles of the eyelids. Pepper in the nose causes sneezing, water down the trachea causes coughing, pinching of a finger causes it to be jerked away. These are examples of natural reflexes. They are responses that we make without learning to make them. An example of a very simple natural reflex is the knee jerk. Cross your legs and with the edge of your hand strike the front of the knee just below the kneecap. If you strike the right place the foot will give an involuntary kick forward. The arcs for the natural reflex responses are in the cord and lower brain. Many of these acts can be carried out perfectly by the cord after the brain has been destroyed.

Acquired or conditioned reflexes. In contrast to the natural reflexes are the acquired or learned reflex actions. Without thought the well-trained soldier raises his hand in salute when he meets his commander. A pianist looks at a sheet of music and his fingers strike the keys that correspond to the notes. In response to a particular call an animal learns to come for food. If for a time a bell is rung as a dog is given food the mere sound of the bell without the food will make the animal's salivary glands secrete. It is possible by training to develop in the higher animals many reflex responses in addition to the natural ones. We ourselves make scores of these learned responses daily. We are accustomed to speak of them as habits, especially when the responses are somewhat complex.

Acquired reflexes are often called *conditioned reflexes*. They are reflex acts that are carried out only under certain conditions. An animal that has learned to respond to certain conditions by carrying out some particular reflex act is said to be "conditioned." Habits are conditioned reflexes of more complexity than simple reflexes. The arcs of acquired reflexes lead through the cortex of the cerebrum. If this is destroyed all learned reflexes and habits are lost.

Guidance of nerve impulse. It is easy to see how a nerve impulse keeps its course along the axon of a long nerve fiber. We have no satisfactory explanation of how it finds the right way in the infinite complexity of the nerve centers. According to what is called the bond theory of nerve conduction, the branches of only certain neurons are in contact. Just as the wires in a building are connected to carry the electricity along certain courses, so are the neurons linked up to form "neural pathways" which the impulses follow. The arcs of natural reflex acts are natural pathways through the nerve centers. When we acquire reflexes



Conditioned behavior. The cat has learned that if he stands up he will be rewarded with food.

and habits we cause other neurons to form more or less permanent synapses through which the impulses flow.

There is little to support this theory; it is offered only because of the lack of a better one. It would require continuous readjustment in the synaptic connections to account for the differences in action which accompany changes in instincts and moods. There is in the theory no suggestion of how the changes in the connections could be brought about.

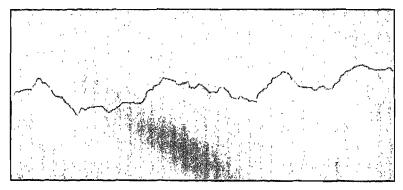
Electrical changes in nerve tissue. When an impulse passes along a nerve fiber a wave of electrical variation accompanies it. It is possible by the use of electrical apparatus to find what parts of the cerebral cortex are being stimulated by sound or by light falling on the eyes, or to find what parts of the cortex are in action when voluntary movements are being carried out. The "brain waves" about which we hear and read are not waves

sent out as radio waves are, but waves of higher electric potential within the brain itself. The whole brain, regardless of whether it is at rest or parts of it are in action, has pulsating electric waves running through it. These waves in their rhythm and intensity differ in different persons. The waves in the brains of persons with epilepsy and some types of insanity differ from the waves in normal brains.

These facts might suggest that nerve impulses and nerve action are electrical in nature, but it is believed that the action is, in part at least, chemical. Nerve tissue uses more oxygen and gives off more carbon dioxide when it is in action than when it is at rest. The electrical change is supposed to be an accompaniment of the chemical action in the nerve fibers and cells.

Overlordship of the brain. The higher centers of the brain can do more than guide and coördinate impulses. They can suppress impulses so that there is no response to external stimuli. They can start impulses when none have come in from the outside.

Move your finger back and forth. The impulses that cause the movements are not reflected ones. They *originate* in the cerebrum and pass down the nerves to the muscles that move your fingers. Hold your eyes open while someone strikes toward



A tracing made by placing the two electrodes of an electrical apparatus on the scalp over the parietal (side) lobe of the brain. When an area of the brain is active, its electric potential rises and the needle of the instrument moves upward.

them. You are suppressing impulses that normally would cause your eyes to close.

We do not know how nerve impulses originate in the nerve centers. We do not understand the control we have over the centers that makes us able to suppress and send impulses out as we wish. We do know the cells of the brain have (or at least they seem to have) the power to build impulses up and to send them out as the conscious intelligence directs. We know that, through what we speak of as the will, reflex and instinctive responses can be suppressed. These powers lift the higher animals above the level of mere automatons. These animals have spontaneity — the power to act from within.

Through its long fibers the nervous system reaches all parts of the body and puts them all into quick communication with each other. In its centers nerve impulses are coördinated, suppressed, and originated. Through its activities the body processes and actions are regulated and appropriate responses to stimuli from without the body are made. We can describe the wonderful operations of the nervous system, but we cannot explain how they are carried on.

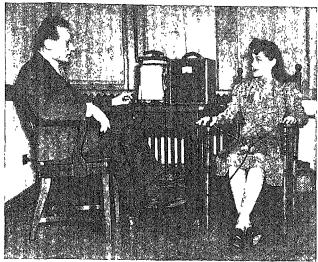
PROBLEM FOUR

Do the Emotions Have an Important Effect on Behavior?

The word "emotion" is used in two senses. It is used to mean a feeling, as of anger, fear, affection, pity, joy, or grief. It is used in a wider sense to include not only these feelings, but also the actions and other responses that accompany the feeling. In this latter sense an emotion is comparable to, or perhaps is, an instinctive or reflex response that is accompanied by feeling. Emotions may be aroused either by external stimuli and situations or by thoughts about persons, objects, or conditions that have agreeable or disagreeable associations. It is generally agreed that man is nearer to other animals in his emotions than in his intellect.

The emotional center. From many experiments on animals it is concluded that the emotional center is in the middle lower brain — the hypothalamus — and perhaps also the thalami above it (page 375). Dogs and cats with all the upper and front brain removed are still violently emotional. If the tail is pinched they fly into a rage, and they are difficult to care for because of their viciousness. Normally the cerebrum is in control of the lower brain centers and can inhibit or change responses that are made through them. When the cerebrum is removed the check on the lower centers is off and emotions have full sway. An animal with the cerebrum removed is much more easily thrown into a violent emotional state than one with the cerebrum intact.

Emotional responses. The responses made to an emotional stimulus may be in part internal ("implicit") and in part external ("overt"). In violent emotions such as rage and fear the heart quickens its beat, the blood pressure rises, muscles and glands of the stomach and intestine go into inactivity, and the blood is cut off from the internal parts and sent to the skeletal muscles. Externally there may be changes in the expression of the countenance (smiling, sneering, frowning), striking, fleeing, pursuing, laughing, crying, or other action.



Psychological Laboratories, Fordham Unia ersity

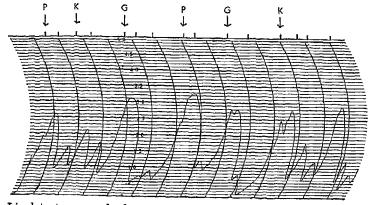
The lie detector, by which the emotional response to a question can be detected. The electrodes are placed in the palms of the hands. A delicate hand on the instrument that moves up and down according to the emotions aroused leaves a tracing, as is shown on page 734.

With electrical apparatus it is possible to measure the intensity of the internal emotional responses. When this is done it is found that there is often little agreement between the violence of the internal and external responses. Some persons who seem outwardly calm undergo great internal disturbance. Some who display vigorous outward action respond only slightly internally. One small girl who had undergone emotional tests, when asked if she had been frightened, replied, "No, but my stomach was." Probably she was one of the type whose emotional response is mainly within.

Feeling and action. The relation between the emotional feelings and the overt actions in an emotional situation is puzzling. When an angry person strikes another we are inclined to take it for granted that the blow was caused by anger. If we saw a man running from a bear we should probably think the running was caused by fear. Yet most psychologists seem to

think that emotional feeling is not a cause of action. A man can be angry without striking and he can strike without being angry. A man could run from a bear without being afraid, or he could be afraid and not run—perhaps so afraid he was unable to run. Many psychologists believe that it is not fear but the sight of the bear and the instinct to get away from such an animal that cause the running. According to this theory the fear accompanies the flight but does not cause it; the situation is similar to that in the carrying out of the reflex described on page 727.

Theory of emotions. The most reasonable explanation of the emotions seems to be that some stimulus from the outside, from the internal organs, or a thought or a memory causes an impulse to be carried into the emotional center of the lower brain. This center then discharges impulses upward to the cerebrum, which results in the emotional feeling. At the same time it sends impulses to the internal organs or to muscles which cause body movements or gland secretion. In violent emotions (anger, fear) the internal preparations are such as to prepare the body for emergency action. Not only does the blood pressure rise, but the spleen contracts and sends more red corpuscles into the blood, epinephrin is secreted by the adrenal



Lie-detector record of a person accused of theft. At the points marked P, K, and G he was asked questions about the crime. (Reproduced by permission from "Science Can Get the Confession," by Rev. W. G. Summers, S.J., in *Fordham Law Review*, Vol. 8, No. 3, pages 334-354; November, 1939.)



J. V. D. Bucher

Rule by the lower brain. The cerebrum is blocked off and the hypothalamus is in control

glands, and the liver throws additional sugar into the circulation. The violent emotions are thus adaptations for life in an environment that may call for sudden and great physical exertion.

Emotional action unintelligent. One notable fact is that in strong emotional states the cerebrum loses control of the actions and behavior lapses back to old instinctive ways. The following explanation of the way the intelligence is blocked off has been proposed: Normally the cerebrum is in control of the lower brain centers, but when the emotional centers are strongly stimulated they build up a *check* against the higher cerebral control. They block off the orders from above and make their own responses. Speaking in terms of the electrical theory of nerve action, we might say that the stirred-up emotional center develops a higher potential than the cerebrum and the impulses from the cerebrum cannot flow down into it.

Whether or not this theory holds, it is certainly true that human behavior that is accompanied by strong emotion is often highly unintelligent. A cool brain rather than one that is suffused with emotional feeling is the one that is in condition to judge of what

is true and wise. When it is desired to rush people into action that their sober judgment might not approve, the favorite method is to stir up the emotions and push the action before there is time for an intellectual analysis of the matter proposed.

Natural and conditioned emotions. Reflexes may be natural or acquired. Likewise emotional responses may be natural or acquired. Emotions arise in some cases because of situations and actions on the part of others that we naturally approve or disapprove. Other situations or actions arouse the emotions because of our conditioning; we approve or disapprove of them because of the way we have been taught. It is possible also to acquire emotional habits just as it is possible to acquire physical habits; a person may very easily fall into the habit of responding to his conditions and to persons about him in definite emotional ways. Because of these facts our emotions are in part under our own control and emotional training is possible.

It is very important that individuals who need this emotional training shall receive it or give it to themselves, for many persons have violent emotions connected not with anything they are doing but with their thinking or with their past experiences. A survey in one city showed that nearly all unemployable persons who were physically able were unemployable because they had allowed the more violent emotions to become tied up with their thoughts. The average person cannot have either mental or physical health as long as he is torn with violent emotions.

The relations of feelings, sentiments, and passions to outward action is not well understood, but the emotions have a great influence on the behavior of the higher animals. We do some things because they are parts of external emotional responses. We do other things to avoid disagreeable emotional feelings. Still others of our acts are for our emotional satisfaction — to arouse emotions that are pleasurable to us. Without emotion there would be no reason for music or art; poetry and the drama would disappear. Certainly the life of an emotionless race of human beings would be vastly different from the life we lead.

PROBLEM FIVE

What Other Factors Are Important in the Control of Human Behavior?

Four important elements in the control of human behavior are the instincts, emotions, intelligence, and habits. The two of these whose influences we have not considered are the intelligence and habits. In how far do these cause human beings to behave as human beings do?

INTELLIGENCE AND HUMAN BEHAVIOR

We might possibly believe that the behavior of a very simple animal is governed by tropisms or even look on a somewhat more highly developed animal as only a reflex and instinctive machine. There comes a point, however, as we ascend the scale of animal life, when the animal does not respond to stimuli from its environment in a fixed, machine-like way. It varies its responses, delays them, or perhaps makes no response at all. Something inside is different. The change is as though an intelligent operator had been placed at the neural switchboard and was taking a hand in determining what messages should go out. Intelligence moves in as manager and helps decide what shall be done.

How intelligence influences conduct. The intelligence affects our behavior by enabling us to see what is wise to be done. It enables us to gain knowledge that gives us wider understanding of the results of actions. It greatly affects behavior by holding a check on instinctive and emotional responses when these would be inappropriate. The intelligence has also a great indirect effect on conduct by influencing habits that will be formed and emotional associations that will be built up. Intelligence is the top factor in conduct control and its influence is increased because the other factors are in part under its control. Some idea of how great the influence of intelligence on human conduct is may be gained by comparing the behavior of normal persons with that of persons who lack minds.

Man's respect for intelligence. It is often said that the mass of people are ruled by their instincts and emotions and that they cannot be appealed to on an intellectual basis. There is, of course, truth in this idea, but yet it is not in entire accordance with the facts. Man respects his intelligence. He regards conduct that is based on reason as more desirable than blind instinctive and emotional acts. The craziest social and economic schemes are all neatly reasoned out and are accepted because of their logical form. The shallowest rabble rouser presents statements that he asserts are facts and from them lays out a seemingly true line of reasoning. Propaganda is usually organized in the same logical form that is used in sincere exposition, and there is no way to detect it except to ascertain the truthfulness of its facts and the correctness of its reasoning.

The fact that men so consistently try to get intellectual approval for their acts and plans in order to have them accepted shows the importance of the intelligence in the control of the behavior of man. All experience indicates that a people can be expected to fall into a desirable permanent set of social habits (customs) only when they know why these habits are desirable. They can fall into very bad ones on the basis of a wrong line of reasoning.

Mental attitudes. Fixed mental attitudes may be thought of as habits of thinking, or rather as habits of not thinking. A person may become accustomed to holding a set of ideas or to taking a set of "facts" for granted, and not thinking on some matters at all. Such a mental attitude is often closely connected with the emotions and it often causes questions that come up for consideration to be swept aside without examination. At times behavior depends to a marked degree on whether one has an open mind that is willing to examine facts and search for truth, or a closed mind that is hostile to ideas it does not already have.

In part, mental attitude is determined by inborn qualities and in part it is a result of education and training. It is natural for some persons to be more reasonable and open-minded than others. A liberal education and wide experience in dealing with the ideas of others tends to give a less rigid and less limited point of view. An ungoverned emotional nature is a handicap.

HABITS AND BEHAVIOR

As we have noted, habits may be considered as acquired (conditioned) reflexes of more or less complexity. Habitual acts are the outward expression of impulses flowing without consciousness or thought over much-used pathways in the nervous system.

Habit formation. In general, habits are formed by repeatedly going through an act and finding the results pleasurable or at least satisfactory. A habit is not formed by the mere repetition of an act without regard to its consequences. No one would form the habit of sticking his finger into a flame. We avoid rather than repeat the acts that give undesirable results. It follows, then, that we will form only such habits as, so to speak, we approve. To acquire a habit we must find an act satisfactory and then repeat it until in an appropriate situation we unconsciously go through it.

What causes an act to be satisfactory to human beings? Leaving out of account such matters as physical pain and the gratification of appetites like hunger and thirst, an act is approved when it does not clash with our instincts, our emotional tie-ups, or our previous habits, and when it appears to the intelligence to be sensible. We cannot, in general, fix habits that are squarely against the great natural qualities of human nature. Neither can we, in general, fix habits that involve effort or sacrifice of temporary comfort for future good without an education on why these habits are desirable.

Fixing and breaking habits. In fixing and breaking habits in laboratory animals it is customary to use a system of rewards and punishments. If the animal runs through a certain passageway or opens a door, food may be the reward. If it performs the wrong act, it may receive an electric shock or be punished in some other way. An animal (like the dog) that cares for approval may be rewarded with petting and praise when it carries

out the act properly, or it may be punished by scolding when it fails. The act is satisfactory when it enables the animal either to receive the reward or to escape the punishment.

In psychologies you will find discussions of the best ways of forming desired habits. The directions boil down to advising that you find what you ought to do and then do it, never allowing any delays or backslidings. For instance, if you have a lesson to prepare at home each evening, first convince yourself that learning that lesson is the thing to do. Then sit down and learn If you will do this for several evenings at the same time in the same place you will soon have the habit. It may be possible to break a bad habit by merely dropping the act, but attaching disagreeable consequences to the act is much more effective. One electric shock caused rats that had formed the habit of dashing through a short cut to their food to take a longer way. Connecting an undesirable mode of action with an unpleasant experience may have its place in a training system. The use of punishment is more effective in breaking bad habits or in preventing their formation than in forming good ones.

Permanency of conditioned behavior. At one time many persons believed that the nature and qualities that a person shows are largely determined by the conditioning he received in his early years. Among students of animal and human behavior this idea does not have the support it once had. Conditioning in an animal is not permanent. Animals drop conditioned reflexes and habits when the rewards and punishments are dropped. Attitudes of mind in persons change with new knowledge and new environment. We must not expect to mold the young in a fixed form and have them retain this form through their lives. A conditioned snail forgot its training in four days. Habits are a very important factor in the immediate control of the behavior, but mere blind habits relating to the smaller affairs of life can be easily dropped and may not be very important in their long-time effects.

The factors that are permanent in the control of the conduct are the instincts, the emotions, and the intelligence. If a customary act is in accord with the instinctive and emotional nature it is natural for it to be kept up. If there is a fixed intellectual belief that the act is desirable there is a permanent motive for keeping it up. Give the original nature and the intelligence opportunity, and they will in time bring mental attitudes and habits into subjection. Social customs change when they are not in accord with the nature of a people or when the intellectual beliefs that have supported the customs change.

Human behavior is in large part at least determined by instinct, by emotions, by intelligence, and by mental attitudes and habits. Instincts and emotions we have; acquired emotional tie-ups, mental attitudes, habits — good or bad — we shall surely form. Our hope is in an enlightened intelligence that will help us to transform our crude instinctive and emotional responses into actions suited to our present kind of life; an intelligence that will show us what habits and emotional associations we should form and give us such an attitude that we shall be desirous of acquiring those habits. We need knowledge among all the people, a willingness to put away passion and prejudice, and a calm resolution to use knowledge as a guide in life. The more complex our civilization becomes and the more the action of one group or nation affects others, the greater is the necessity that human behavior be put under intelligent control.

DUTY OF INTELLIGENCE

"All the problems of mankind could easily be solved if people were only willing to think." NICHOLAS MURRAY BUTLER

It is believed that mental capacity — the ability to reason — comes chiefly by inheritance. Yet even if we cannot enlarge the powers of our minds, we can learn how to use these powers and gather information that will allow them to function. We must day by day make intellectual decisions as to what course we shall follow. The way we decide and what we do depends greatly on whether we are trained to gather information before coming to conclusions and to think down to a fact basis.

In the first unit we emphasized the value of science and of the scientific method. We pause to reëmphasize it here. The whole effect of the spread of scientific knowledge and of the scientific attitude of mind is to bring under rational control an ever extending field of human activity. It is well that this is so; for in his lower brain and the instincts that are seated in it man is not in the least superior to many other vertebrates. He fights as do silly little fish with cerebral hemispheres the size of split peas. He struggles for power and place and organizes bands to loot and kill his fellows. It is only in his intelligence that man excels, and when he fails to follow his intelligence he sinks even below the level of many of the brutes.

Social reformers and uplifters and those desiring to direct others, in general, usually believe that even though their acts later prove to have been unwise they should at least have credit for their good intentions. William James, the noted philosopher and psychologist, said, "I find no warrant either in Scripture or in human experience for this belief." Professor James's general position was that deeds stand alone. They are good or evil in themselves. The righteousness or wickedness of an act is determined not by the motives that prompted it but by its consequences. If these ideas are accepted, it follows that to use the intelligence that has been given him is the highest duty of man. "We cannot be good unless we are wise."

UNIT COMPREHENSION TEST

- A. Define: tropism; geotropism; phototropism; chemotropism. Give examples of each. Mention some facts about tropisms that are important for an understanding of their effects on behavior. Explain what is meant by the mechanistic conception of behavior.
- B. What is an instinct? Give examples of instinctive acts of hens and chicks. Give accounts of instinctive acts of the solifuge and scorpion; the pika; Pronuba; a parasitic tropical American fly; a burrowing wasp. Mention some characteristics of instinctive responses. Give examples of changes in instincts. Do instincts have an important effect on human behavior?
- C. What is meant by irritability and conductivity? What is one of the chief functions of the nervous system? What advantage is there in a central system? Define: associative neuron; synapse; reflex act; reflex arc; afferent or sensory and efferent neurons. (Page 493.) Explain how a reflex action is carried out. Define and give examples of natural reflexes; of acquired or conditioned reflexes. With what part of the nervous system are conditioned reflexes connected? What change accompanies activity of nerve and muscle tissue? What is meant by "spontaneity"?
- D. Where is the emotional center of the brain? What internal and external responses may be made to an emotional stimulus? State the theory of the emotions. Explain why emotional action is unintelligent. Distinguish between natural and conditioned emotions. Why for many persons is emotional training very important? Some persons believe that when we speak of a mental attitude we are in many cases referring to an emotional association. Does this seem to you to be correct?
- E. In what ways does intelligence affect conduct? Mention facts indicative of man's respect for his intelligence. What do we mean by "mental attitudes"? How are they determined? What is a habit? How are habits formed? What causes acts to be satisfactory to us? What methods are used in training animals? What general rule may be given for the formation of desirable habits? How may habits be broken? What is necessary to make conditioned reflexes permanent? What are the permanent factors in the control of human behavior? Why is it a duty to be intelligent?

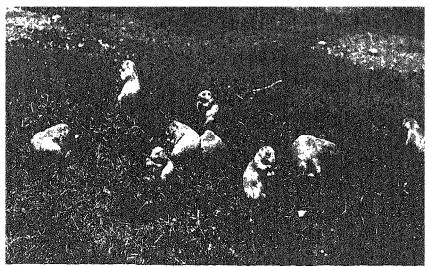
SUGGESTED ACTIVITIES AND APPLICATIONS

- 1. Germinate in moist sawdust pea or bean seedlings. Pin a seedling crosswise to a narrow piece of thin board. Set the board upright in a glass vessel so that the seedling is in a horizontal position. Pour some water in the bottom of the vessel and cover tightly. Make sketches to show the result.
- 2. Place earthworms in a flat pan lined with moist filter paper. Lay a glass over the pan to prevent drying. Then cover a part of the glass with something to exclude the light. Do the worms seek the dark or the light?
- 3. Place several flies in a long piece of large-caliber glass tubing and stopper each end of the tubing. Lay the tubing with one end to the light. Do the flies go toward or away from the light?
- 4. Grow sensitive plants and experiment with them. How is the movement of the leaves brought about?
- 5. Find insect eggs and raise the young away from contact with adults of the species. Do the offspring act the same as the parents? Would a mosquito raised in an aquarium know how to bite?
- 6. Train a cat or a dog until it is conditioned to go through a certain act. What methods that were effective did you use in the training?
- 7. Form a habit until you go through the act unconsciously. For example, always put your hat or books in the same place when you go into the house.
- 8. Can you select three subjects on which you could not argue with one of opposing views without emotional excitement?
- 9. It is said that animals prefer to associate with those of their own kind and that some of them resent even variations in color in their own species. This "preference of like for like" is supposed to aid in the establishment of new varieties, since those having the same characteristics will mate together.

Read Cherry Kearton's *Island of Penguins* (Robert M. McBride & Co., New York; 1931) and report on anything in the book that supports this view.

References

- HORNADAY, W. T. The Minds and Manners of Wild Animals. Charles Scribner's Sons, New York; 1922. Interesting because the author discusses not only the intelligence of animals but also their characters.
- THORNDIKE, EDWARD L. Human Nature and the Social Order. The Macmillan Company, New York; 1940. Includes in its contents a scholarly discussion of the original nature of man and of the social arrangements to which this nature is fitted.



New York Zonlogical Society

UNIT 17 ANIMAL COMMUNITIES

Animals live in accordance with their natures. Relationships within an animal group are determined by the nature of the animals composing the group.

ANIMAL WAYS OF LIFE

QUESTION FOR CLASS DISCUSSION

Do human beings prefer living in the same way at all stages of their lives?

A GROUND HOG lives alone. As soon as the young are old enough to care for themselves the mother drives them out. She wants neither husband nor children around her house, and the rest of the family agree to the wisdom of the arrangement. Ground hogs live this way because it is their nature to do so. Their instincts make them solitary. It would be useless to try to show one of them the advantages of living in a colony with a lot of other ground hogs. A ground hog lives by itself; it is going to keep on living by itself; and that's that, no matter what anyone else thinks or says about it.

Prairie dogs live in villages. Each family has its own house, but prairie dogs dig their holes close to each other, so that when one sits at the entrance to its burrow it has neighbors about it. You might carry a prairie dog out and show it a better grass supply away from the colony; you might show it the solitary burrow of its ground-hog cousin and the ground hog, fat and successful, living by itself. The prairie dog would go right on living as others of its kind do. If you took it out into the country and turned it loose, its one idea would be to get back to town. It has a prairie-dog nature; it will live in a prairie-dog way; and that's that, so far as a prairie dog is concerned.

Animals reveal their instincts by the way they live and by what they do. While each one has the problems of taking care of itself and rearing young so that the species will go on, animals of different species meet these problems in a multitude of different ways. The lower animals are impelled to their activities by tropisms and instincts. Intelligence helps the higher ones to adapt their actions better to varying situations, and they are not so fixed in

their ways of life. Each species of animal, however, no matter how intelligent, has activities and ways of doing things that show its instinctive nature and reveal innate wants that must be satisfied to allow the animal to lead a contented life. The director of a zoölogical garden well understands the necessity of allowing each animal an outlet for its natural desires. A monkey must have a chance to climb and a badger needs to burrow. Some animals will die of lonesomeness if they are not provided with companionship, and some must be left alone. The ideal zoölogical garden would be one that provided a natural habitat for each of the animals found in it.

We know the lives and ways of our domestic animals fairly well, although if an outdoor cat or a farm dog could give a full account of what it had done in the last month we should probably hear some surprising tales. Of the lives of most wild animals we really know very little. There is no more fascinating subject for study than the social conduct of animals and in this unit we shall deal with that theme. We hope you can continue the study for yourself and can include in it that always surprising and puzzling species known as Homo sapiens, to which you yourself belong.

Problems in Unit 17

- 1 How is a beehive organized?
- 2 What is life like among the beavers?
- 3 What group organization do we find among animals that live in packs?
- 4 What social organization is there among flock and herd animals?
- 5 How are monkey and ape societies organized?

PROBLEM ONE

How Is a Beehive Organized?

"What is not good for the swarm, neither is it good for the bee."

M. AURELIUS

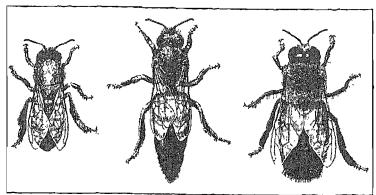
How would you like to belong to a family that had one mother and 100,000 children? And how would you like to live with your mother and all your brothers and sisters in one house?

If you were a honeybee you might be one of a family of this size, and you would probably live with all the rest of your family in a hive, or little house. Maybe you think you wouldn't like being in such a crowd, but if you were a bee you wouldn't mind it. Bees are like that. Anyhow, lots of wonderful things go on in a beehive. Let us suppose we have an observation hive with glass in the sides, and can look through the window into a bee home.

It is a busy place. Some bees are coming and going, bringing in honey. Some are building honeycomb. Some are feeding the young bees. Some clean the hive. Some are standing like sentinels at the door, watching that no robbers get in to steal the honey. If the day is hot, some go down to the front door and fan with their wings to drive the hot air out. A whole wonderful little world is inside the hive. Looking at it is like being in some faraway country and watching a little people very different from ourselves.

Three kinds of bees. As you watch the bees you see that nearly all of them are of the same size. These are the workers. Here and there you might see a few bees that are a little bigger and heavier. These are the drones. Then in each hive there is one bee bigger and heavier than any of the others. This is the queen. There are three kinds of bees in each hive.

The workers are females, but they do not lay eggs. They do the work and run the hive. Usually there are from 20,000 to 100,000 workers in a hive.



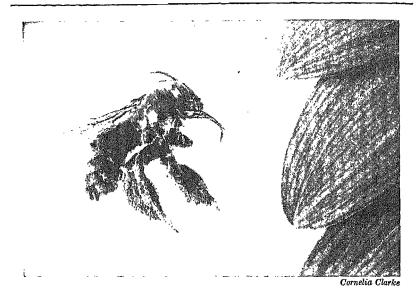
U. S. Dept. Agriculture, Bure su of Entomology and Plant Quarantine

A worker, a queen, and a drone bee. The worker is an imperfectly developed female. The drone comes from an unfertilized egg.

The drones are the males. Their only use is to mate with the queen. In the hive they stand or crawl uselessly about among the busy workers. They are even fed by the workers. They have no sting, and when autumn comes the workers drive them out of the hive and let them perish. The workers allow no idlers to eat the precious honey stored for winter use. Even at the season when the drones are most abundant there are only a few hundred of them in a hive.

The queen is the mother bee. Her job is to lay eggs from which new bees are hatched. The workers build honeycomb and the queen lays an egg in each cell. Sometimes she may lay as many as six thousand eggs in a day. In the busy season the life of a worker is short and many new ones must be raised to do the work. There is only one queen in a hive. All the workers are her daughters and all the drones are her sons. Some hives are better honey producers than others because the daughters of some queens are more industrious than are the daughters of other queens.

Activities of workers. Whoever called the smaller female bees "workers" certainly gave them the right name. Even the young ones never play. They are earnest, intense little beings that do nothing but work. If you put a bee colony in an empty



A worker with full pollen baskets. Sometimes a bee collects so heavy a load that it must climb a weed or tall flower to take off.

hive and they accept it as their home, the workers at once get the industries of the new settlement under way. If the hive needs cleaning, some of them start scraping the frames and inside walls and throwing out any bits of refuse. If there are crevices that need stopping up, some go on a hunt for gum which they scrape from plants and use to make the home weathertight. Many speed out to the fields and begin gathering pollen and nectar from the flowers. Food for daily use must be brought in; young bees must be reared; and supplies for winter must be stored.

Honey and beeswax. When a bee sips nectar from the flowers the nectar goes into a kind of first stomach, or honey sac. Here the double sugar (sucrose) of the nectar is digested and converted into glucose. By the time a bee gets back to the hive the nectar has been changed to honey. Honey is stored in the cells of the comb.

The honey serves as food for the colony and it is also the raw material from which wax for building the comb is made. Wax is a fat, and bees can transform the sugar of the honey into wax. A number of bees hang themselves up in chains, each one holding to the legs of another, inside the hive. Others feed them honey until they are stuffed with it. By the metabolism of the bee the honey is turned to wax; then the wax is secreted by glands between the rings of the abdomen (mammals have glands that secrete wax in the ears).

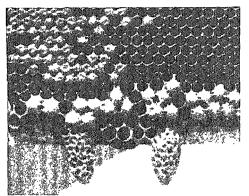
As the wax appears other workers scrape it off and carry it away for building the comb, in which honey is stored and the young bees are reared. The comb is made up of six-sided cells, beautifully regular in their construction. The ordinary-size cell is about five to the inch, measured across the top. Occasionally the bees build a cell of larger size that measures about four to the inch.

Work of the queen. Young bees must be raised to take the place of the workers as they grow old and die. When the brood comb is ready the queen goes into action. She crawls over the comb, placing an egg in each open cell, and in this connection we find one of the strange facts of biology.

When the queen mates with the drone, she receives a supply of sperms that are carried in a small sac and may remain alive during the life of the queen — two, three, or four years. When the queen lays an egg she can allow some of the sperms to come in contact with it, and if she does this and the egg is fertilized a female bee hatches from the egg. If she does not allow the escape of sperms with the egg and the egg remains unfertilized, it develops into a drone bee. A fertilized egg develops into a female. An unfertilized egg does not perish as unfertilized eggs ordinarily do, but grows into a male.

This arrangement results in the female bee having two sets of chromosomes (one from the egg and one from the sperm) and the male bee having only one set. As the queen crawls over the brood comb she lays fertilized eggs in the cells of ordinary size, but when she comes to a larger cell she lays an unfertilized egg and this becomes the larger-sized drone.

Rearing of workers and queens. Both the workers and the queens are females. What is the difference between



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The comb cells at the top are of ordinary size. Across the bottom are some of the larger ones in which the drones are reared. Extending downward at the base of the comb are two queen cells.

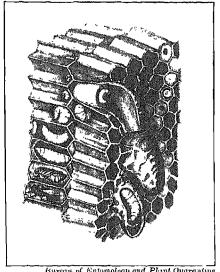
them? The workers are stunted, or dwarfed, by an incomplete diet during their period of growth.

When a worker egg hatches into a larva, the bees feed it first with predigested food which they obtain by eating honey and pollen, digesting them, and bringing them up again. The young worker is given this food for a day or two and is then fed with

a mixture of honey and pollen without its being predigested. On this diet the larva grows, and in about six days it is ready to pupate. Then the bees seal the mouth of the cell with a thin coat of wax, the larva goes into the resting stage, undergoes its metamorphosis, and in about twelve days emerges as an adult worker bee.

When the bees wish to rear a new queen, they first cut away the separating walls of several cells of the comb and throw them together into one big cell; also they build up the walls of this cell until it is deeper than the ordinary one. Then they place an egg or very young larva in this enlarged cell and feed it on a special predigested food that is called "royal jelly." This jelly contains a larger proportion of pollen than the diet the worker larvae receive and is said to be much richer in vitamin E. It also contains at least one hormone secreted by the worker bees. The interesting point is that with one diet the larva from a fertilized egg develops into one kind of small animal with a very definite set of instincts; with a different diet the same larva could have been made to grow to a definitely larger size and to have had a different set of instincts when mature.

Adaptations of structure. If you wish to study bees you will find in their structure much of interest. The workers have "pollen baskets" on their hind legs. They carry in these baskets loads of pollen which they store in the comb as "beebread" and use as part of the food. Each bee has two large compound eyes with more than six thousand facets in each, and on top of the head are three smaller eves. There are olfactory pits in the feelers in which the organs of smell are located. Bees have crossed a mile of water to reach



Bureau of Entomology and Plant Quarantins

How the young bees are reared. left side of the picture shows the development of a worker from the egg to the adult stage. The right shows queen cells and queen larvae.

flowers, supposedly attracted by the odor. The two wings on either side are securely fastened together by a row of little hooks on one wing, which lap over a heavy rim on the margin of the other wing. With a microscope you can easily see the hooks. They hold the two wings together so that they work as one. At the back of the body of the workers and the queen is a stinger, one third the total body length, with poison glands attached. Think what an enemy a man would be who had a sharp hollow sword through which he could squirt deadly poison into a wound! Is it any wonder that when two queens fight the combat is always to the death?

The behavior of bees is even more interesting than their structure. They build their comb with marvelous perfection. They rear the young successfully. Ordinarily when the larvae are grown they cap the cells that contain the pupae; but if the weather is hot they leave off the caps, and the heads of the pupae show "like corpses in a row." Honey will ferment unless it is



A swarm of bees. If left alone they will, after resting for a time, move on to a home already selected and prepared.

so concentrated that the sugar prevents the growth of bacteria in it, and after placing the honey in the cell the bees before capping it fan it with their wings until sufficient water has been evaporated from the honey to insure its preservation. In early summer queen cells are started in the hive, scouts go out and locate and clean up a new home (usually in a hollow tree), and when a new queen hatches, a part of the swarm takes the old queen along and moves out. The speed of a flying bee is about 20 miles an hour.

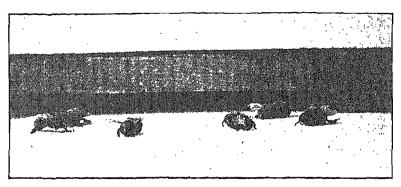
Organization of colony. Our particular interest is with the social

organization of the colony, and the first point to notice is that it is run strictly by the workers. In ordering the affairs of the community, the lazy drones and the fat queen do not count. The energetic little workers are the ones that bring in the honey and the pollen, rear the young, clean, ventilate, and guard the hive; they decide when a new queen is to be reared and a part of the colony is to go out with the old queen to a new home. These workers we can consider as neither male nor female. They are not troubled with "falling in love." They have no husbands or wives or children to occupy their attention. They are a third class of beings, entirely different from anything found in human society. You can think of them as slaves taking

care of the drones and the queen; or you can think of them as rulers that keep the drones only as long as they may be useful and that hold in captivity a queen who must wear out her life laying eggs. Whether slaves or rulers, the workers run things. The queen has no authority to do anything but lay eggs.

In the bee community everything seems to be done by instinct. There is no school in a beehive. A young bee knows without instruction how to build comb or feed the young. It follows the gueen as an attendant or helps store the honey without being Each bee seems to choose its own job and there seems taught. to be no compulsion on any bee to work if it should see fit not to There is no driving of the workers, no dividing of them into squads to do this or that. It would seem that from such a plan nothing but hopeless confusion could result, but we have the seemingly impossible combination of complete freedom and perfect order in the hive. Most biologists are inclined to believe that a bee has practically no intelligence at all (bees may try to raise a queen from a drone egg) and that each one reacts automatically to its environment as a moth reacts to the flame. Possibly you would not call it freedom to be under the compelling force of instincts — even if they were your own — over which you had no control, or perhaps freedom consists in being allowed to follow instincts. We leave it to you to think about that as vou choose.

An additional fact of interest is that in their instincts the workers are wholly without individualism. They lack entirely any desire to have and own anything privately. The honey they bring in is placed in a common store. Each one unhesitatingly goes to the defense of the colony, and when one stings a tough-skinned animal (as a man or a dog) it cannot withdraw its sting and so loses its life for the common cause. When a young queen "pipes" in a cell before hatching (as they do), the workers prevent the old queen from tearing open the cell and destroying her. Some of them move out with the old queen and leave the stores in the hive to others. When a worker becomes old and her wings are worn out she crawls away from the hive and dies.



Drones driven out to die. In the beehive there is no sentiment or sympathy. The individual is nothing and the colony is all.

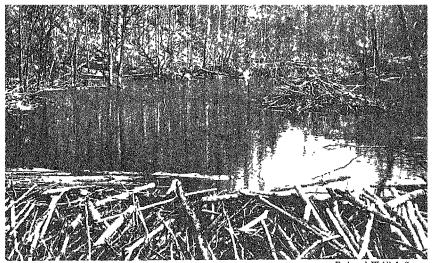
We might say that a bee has no thought (if a bee has thoughts) for its own welfare or safety but only for that of the community and the race. The group, and not the individual, is the center about which bee society is built. "The hive has a common voice built up of a thousand imperceptible murmurs."

Bee ethics. In a hive a bee is a model resident. It does what it ought to do and does not do what it ought not to do. Its society is suited to its nature perfectly; or, if you prefer, its nature is suited to its society. What about its relations with other bee colonies?

Outside of its own hive relations, judged by human standards, a bee is the lowest kind of criminal. It is so confirmed a robber that every colony must keep sentinels posted inside the door to seize intruders from other colonies who would make off with the honey. If a colony becomes weak, other bees will rob that colony of its last ounce of honey and leave its members to starve. Few animals make war on their own kind, and bees are among the few. They carry on war against their neighbors — unprovoked, aggressive war — for no higher motive than loot. The individual bee within the hive may have morality, but the group has none.

What can we learn from the bees about organizing our own society? Nothing. We are not bees. They belong in the

arthropod line and we in the vertebrate. In relationship and in our natural ways of doing things we are far removed from them. The social insects — bees, wasps, ants, termites — are in their instincts perhaps the most highly specialized of all animals. In some termite colonies there are as many as eight kinds of neuter individuals. Among them the individual is nothing, and their society is merciless to the individual. Theirs is a society controlled by machine-like neuter forms driven on by ruthless, blind instincts for the preservation of the race. The life within a colony is wonderful to contemplate, but to a creature with individualistic instincts and intelligence it is also terrible.



Fish and Willise Service

A beaver dam and pond. A lodge is shown at the right of the center of the picture No other animal except man modifies its environment as the beaver does.

PROBLEM TWO

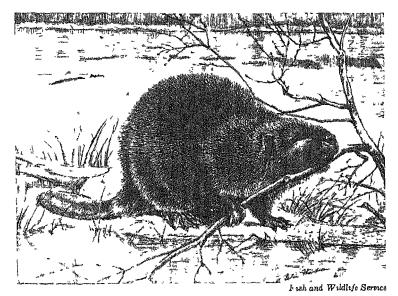
What Is Life Like among the Beavers?

At one place and another over a great part of the United States you are likely to find a small stream called Beaver Creek or Beaver Brook. There are seven Beaver Rivers and there are many towns with such names as Beaver Falls and Beaver Dam. These names remind us that over the whole timbered part of our Northern and Eastern states the beaver was once abundant. This animal yielded a valuable fur and beaver skins were once one of our principal exports. Beaver flesh is edible and the Eastern and Northern Indians depended on the beaver for meat much as the plains Indians depended on the bison. Many more books and articles have been written about the beaver than about any other of the North American animals. Formerly it was believed to be almost human in its intelligence and one old book shows a beaver lodge fitted with glass windows and hinged doors. What kind of creature is the beaver and to what qualities did it owe its great success?

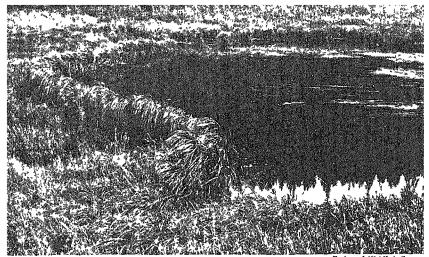
The beaver and its achievements. The beaver is the largest of the rodents, excepting the South American capybara. A full-grown one weighs 40 to 60 pounds. It is reported that huge and very fat old ones weighing 100 pounds have been captured. Like most other rodents, the beaver lives on vegetable food, its diet in summer including herbs and sometimes grass, and in winter consisting almost wholly of twigs and the bark which it peels from larger pieces of wood.

On land the beaver is clumsy and slow of foot. In the water it is at home. It is able to remain under water for a long time (five minutes easily) and it swims well by kicking out its webbed hind feet after the manner of a frog. Its special physical equipment consists of a pair of jaws and a set of incisors that have made it the best natural lumberman of the animal world, and of front limbs and paws that are little short of arms and hands.

But the fame and the success of the beaver rest not on the power of its teeth and limbs, but on the invisible connections of its nervous system. The beaver is a builder, an engineer. There



A beaver. Its cutting teeth place it next to man as a lumberman and its front paws are almost hands.



Fish and Wildlife Service

A beaver dam made of mud and grass. In their building operations the beavers use almost any material they can find.

is a beaver civilization. This animal does not merely occupy the pools suitable for its habitat that nature has provided; it builds dams and increases the natural number of pools a thousand-fold. It builds houses that are better than those occupied by some tribes of men. It digs long canals that enable it with less danger to reach additional food supplies and in autumn it lays up a food store for the winter months. If we except man, the beaver among mammals is in domestic economy in a class by itself. It works to distant ends; it has the skill and persistent industry to carry out its undertakings; it has the social character that fits it for community life and coöperative effort. It is a truly remarkable animal and worthy of all the interest it has aroused.

How beavers build a dam. A beaver colony often starts from a single pair. If the pair can find a pool or a pond that suits them they will build their home in it; but if no pond is at hand they make one by damming a small stream. They do not mind water and mud, and dislike of getting its hands soiled does not hinder a beaver in its work. A single pair does not he he construction of a dam, but sometimes a whole

colony moves and there are more hands for the work. Only a small stream is ever dammed. Too much overflow would wash out the dam.

The beavers begin a dam by cutting brush and dragging it to the selected spot. They lay the brush with the twig ends downstream, and weight the upstream butt ends with mud or stones. They bring more brush, and scratch up mud and carry it from above the dam to hold the brush in place. If rocks are at hand they bring ones as large as they can carry and build them in. Sometimes they choose a place where a tree has fallen across the stream to begin a dam, and they will use quite large poles if these are conveniently near. The materials they use depend on what is available. In North Dakota some beavers built three dams principally of coal which they mined from the side of a bluff near by.

At first a beaver dam leaks, but the workers keep plastering the inside with mud, which is washed into the crevices until the dam becomes watertight. In California an irrigation dam was built and when the water was impounded the dam did not hold. Several times the water was let out and expert engineers looked for the crevices but failed to locate them. Then a pair of beavers moved in and stopped the leakage. In some way they found the weak spot and plugged it tight. In Maine a dam holding back water for driving the machinery of a woolen mill was leaking, and attempted repairs had failed to correct the trouble. A colony of beavers moved in, and since they had an interest in the pond they came down at night and repaired the dam.

The industry of beavers is proverbial, and the amount of material they use in building a dam is enormous. A new dam across a small stream is usually not very long (10, 20, 30 feet), but beaver dams up to nearly 100 feet in length are not out of the ordinary. A beaver dam in Yellowstone Park that caused the formation of Beaver Lake and was doubtless worked on by generations of beavers is 1054 feet long. The height of a dam must be sufficient to give a pond not only of some size but also deep enough not to freeze to the bottom. Perhaps 3 to 5 feet



A canal extended out from a beaver pond. The canals enable the beavers, without leaving the protection of the water, to reach a greater food supply.

is the average height of a new dam, which at the base may be perhaps 15 feet across.

Beavers work rapidly. One that was watched cut down a 4½-inch aspen tree, cut off 8 feet of the butt, and dragged the top into the stream in less than 20 minutes. Saplings or branches 1 or 2 inches in diameter often carried on land in lengths up to 10 or 12 feet. Much larger poles can be handled in water. Thompson Seton reports that one night when he was camped near a beaver colony the beavers placed on the dam a

pine pole 18 feet long and 5 inches in diameter.

Reaching a greater food supply. Beavers live chiefly on the twigs and bark of shrubs and trees (aspen is their favorite food in the North), and after a time they cut all small trees that are near their pond. They keep close to the water, for this is their safety, and to do this they must bring the water to new timber supplies. They often raise the dam and so extend the pond. It is common, too, for them to build dams above and below their home and thus form new ponds adjoining the old one. Then a beaver can swim to the end of the pond in which he lives, climb over the dam, and go on by a water route to the new food supply. He can cut a piece of wood at the far end of the new pond and float it on to his house. Not only does the extension

of the water give greater safety; it also gives a way of bringing home wood that is far easier than dragging it over the land.

The beaver may extend his water routes still more by long canals dug out from the margins of the ponds. These may be perhaps 18 inches deep and 2 or 3 feet wide. Some of them extend back into the timber several hundred feet or even 1000 feet. The beaver swims up these canals and thus reaches the trees that he wishes to cut. He floats his wood down the canal to his home. Sometimes where a small side stream comes into the pond from higher ground he will build across it a series of dams that will form narrow ponds on successively higher levels. After a time the food of the locality will probably become exhausted and the beavers will move to a new site.

The beaver lodge. The house, or lodge, is built in the pond and the entrances are deep under water. On the bottom of the pond (preferably in a shallow place) a heap of mud, sticks, and perhaps stones is collected. Holes for entrances are kept open through this, and when the heap rises above the water line rather heavy poles are built together, along with brush, so as to leave a room inside. A typical lodge is some 20 feet across at the base and 3 to 5 feet above the water.

The floor of the living compartment is above the water level and several underwater entrances open into it. From the outside a lodge looks like a heap of brush and sticks. It is plastered with mud on the inside (very rarely on the outside also), but is kept open enough in the roof to allow ventilation. The walls of the living room are 2 feet thick, the ceiling is 18 inches or 2 feet high, and the room may be 5 or 6 feet across. Sometimes several lodges will be built against each other and several beaver families will live in this apartment house. Each family, however, has its own separate compartment with separate outlets.

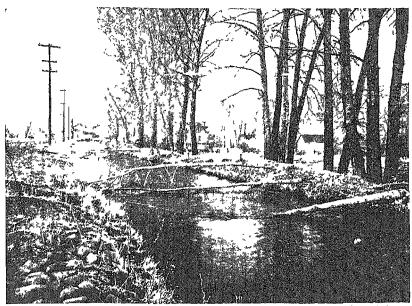
Beaver life. Usually there are four "kits" in a beaver litter (there may be more), and they are born in the spring. The young stay with the parents until the end of the second winter; so a family consists of the parents, yearlings, and kits. A family probably averages about eight members. Nearly all the work

seems to be done by the heads of the families. The little beavers spend their time in play.

When it is time for the kits to arrive the male beavers and the children of the year before leave the colony to the mothers and go roaming. The old males spend the summer along the streams, sleeping in burrows in the banks; or sometimes a group of them live together in a bachelor lodge. In late summer they come back and prepare for winter. The dam is repaired, the houses are put in order, and brush and wood for winter food are brought home and stored. They fell trees of 4, 6, 8, and 10 inches in diameter, and have been known to fell one 3 feet in diameter. They cut the trees and brush into pieces they can handle, drag them into the water, and float them home. When timber must be carried on land, a log 5 inches in diameter is usually cut into pieces about a foot long; 4 inches in diameter into pieces about a foot and a half long; 3 inches in diameter into pieces about 2 feet long.

The beavers sink their wood and brush to the bottom of the pond beside the lodge and weight them down with mud or stones. Then when winter comes and a beaver is hungry he goes down, brings a stick up into the lodge, peels it, and has his meal. Like the bees, the beavers hold to the economy of abundance and they "work like beavers" getting in a sufficient food supply for all. There is no quarrel about how much each one shall have. The families in a colony usually number from one to five. A larger colony would exhaust too quickly the food supply of the neighborhood.

Beavers are adaptable and they may live in rivers or lakes, where instead of building lodges they dig burrows in the banks. There are rogue beavers, supposedly driven out from the colony, that live by themselves. Formerly some observers conjectured that they were exiled because they would not work. It seems more probable that they have lost their mates and are extra males. In the National Zoölogical Park at Washington a beaver was bitten and chased by the others until he had no choice but to move upstream and set up an establishment of his own, where he



Fish and Wildlife Service

Cottonwood trees cut down and thrown across an irrigation ditch by beavers.

dwelt in dejected loneliness, looking at his former companions but unable to join them.

Defense from enemies. Beavers are remarkably successful in escaping their four-legged enemies. When one is at work another watches. A working group will always have a watcher. If danger is sighted, slap goes the sentinel's flat tail and all take to the water. The lodge protects them from wolves, panthers, and wolverines. Even if a bear should tear the roof open (which bears do not trouble to do) the occupants would slip out under water and perhaps peep up at the far side of the pond. Otters excel the beavers as swimmers and a single otter (an otter is a great weasel) would probably be able to kill a beaver; but there are records of beavers combining forces against an otter and driving him away crippled and bleeding. The beaver's house is his castle, his pond is a moat that only a swimming animal can cross, his secondary ponds and canals allow him always to be

close to water, and the great incisors that cut down trees can be used efficiently for defense. By his skill in construction, his industry, his fighting power, and his coöperation with his fellows the beaver easily holds his place in the world except when man interferes.

Organization of beaver society. Each beaver family has its own home and lives as a unit, but a number of families usually live together in a community. Together they own the dam and pond. They work together. When they are outside the houses someone always stands watch while the others are left free to eat or play. What we see in a beaver colony is a group of animals that prefer to live together rather than to live solitary or in pairs. We see them living together harmoniously, not envious of each other, not ordinarily finding fault with each other. We see in this community each citizen seemingly industrious and doing his part. All in all, the beaver seems to be a high type of citizen as well as king of the animal engineers.

In the United States the beaver was almost exterminated, but it is pleasant to report that he is coming back. Probably you will sometime have a chance to see him at work. How much of his behavior is instinctive and how far it is governed by intelligence we leave others to judge.



Wolf pack stalking a deer.

PROBLEM THREE

What Group Organization Do We Find among Animals That Live in Packs?

"As the creeper that circles the tree trunk,
The law runneth forward and back,
The strength of the pack is the wolf,
And the strength of the wolf is the pack."

KIPLING

Among the bees and the beavers there is equality. All have equal rank. There is no leader imposing his will on others. Each does what is right in his own eyes without compulsion from others. Among dogs and wolves the situation is different. In the pack freedom and equality are gone; dominance and subjection are the rule.

Pack organization. The pack is best developed among the Canidae — the dogs and their relatives. Wild dogs, wolves, jackals, and hyenas form hunting packs. Wolves live by families, and a large wolf pack is made up of a number of families that know each other and come together only temporarily for hunting purposes. Dogs are much more highly socialized than wolves, and wild-dog packs are more close-knit. The red dog of India (the *dhole* of Kipling's stories) and the disagreeable Cape dog of South Africa spend their lives in permanently organized large bands. After the World War of 1914–1918 dogs in the devastated portions of Poland formed numerous wild packs. A pack would contain twelve or fifteen members and be made up of dogs of all different sizes and breeds.

In a pack of dogs there is a leader who must be obeyed. Moreover, from the top dog down each dog knows his rank. He rules some dogs and obeys others. Within a pack there is a struggle for power, and rank seems usually to be decided by contests of strength. The best fighter stands highest. If there is any deposing of a leader because his lack of wisdom gets the pack into trouble, we do not know of it. And the ceremony of deposition would in any case consist of a fight to the death. Certainly there is no abstract justice in pack rule. When two dogs are kept together where the supply of food is limited, the stronger takes it all. The under dog does not resent this. If he were in command he would do the same thing.

Strength and weakness of the pack. The advantage of the pack is that it permits cooperation. The strength of the individual is multiplied and the pack can accomplish what no individual in it can. Wolves will drive a deer toward others of the pack hidden along a trail. Individuals from a Cape-dog pack will slip around a cow and chase her into the midst of a pack that will in an instant pull her down. So terrible is the power of the pack that the dogs of South Africa are more dangerous than lions and leopards as the enemy of herbivorous game, and a red-dog pack of India has been known to drive a tiger from his kill and up a tree.

The weakness of the pack is that the moment the quarry is down the society turns from a coöperative to a highly individualistic and wholly selfish one. Each dog or wolf is snarling at his fellows and struggling to get as large a part of the spoils as possible for himself. The whole organization is much like that found on a pirate ship. The members of a pack want the help the others can give, but they are not willing to share with others the results of the cooperative efforts. The stronger members take what they wish without regard to the welfare of the weaker members. The pack as a group does not accept responsibility for the welfare of all its members.



The Cape dog of Africa. It hunts in especially well-organized packs.

Probably if the leaders of a pack had enough for themselves they would not continue the hunt until all were satisfied.

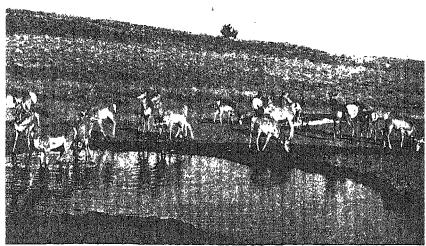
Pack animals only partly socialized. The pack results from the instincts of the animals in it. The members are gregarious and therefore they prefer to live in groups. The worst-abused member of a pack will stay with the crowd rather than live alone. Pack members are socialized, too, in the instincts which show themselves in their coöperative efforts to obtain food. In the chase each pack member gives of his best efforts to secure the prey.

The instincts that govern the other relations of pack members are distinctly individualistic. The pack is ruled by force and within it there are jealousy and a constant struggle for place. There is no storing of a common food supply among pack animals as there is among bees and beavers. When a dog buries a bone he does it for himself alone.

Temporary hunting associations. The European stoat (weasel) is said sometimes to hunt in bands, and pelicans and cormorants are reported to aid each other in fishing. The birds form a circle and swim toward each other, or they form a half circle and swim toward the shore, driving the fish before them. Several lions sometimes hunt together and the mother lion habitually takes her partially grown offspring with her as assistants on her hunting trips. Such hunting bands are not

organized after the manner of a permanent pack. There is no set system of social rank in it and the association of members is only temporary.

The outstanding social quality of the pack animal is that he cannot live with others on a basis of equality. He must be master or servant; he must look up or down. This trait leads to jealousy and a continual struggle for power within the pack. It banishes fairness and justice and leads to a rule of force. The most unlovely traits of Homo sapiens are rooted in his pack instincts.



Fish and Wildlife Service

Pronghorn antelopes. In the earlier days of our country millions of these animals were found on our Western plains. They were the most important native herd animal except the bison.

PROBLEM FOUR

What Social Organization Is There among Flock and Herd Animals?

Mosquitoes and gnats may dance in swarms in the air; some kinds of fishes live in schools; birds often gather in flocks; among herbivorous animals such as sheep, goats, cattle, horses, antelopes, and pigs life in groups is the rule. In these bands the relationships existing between the different members vary according to the species. Some animal assemblages seem to be formed from sheer gregariousness—the instinct to be with others of the species. In these assemblages there is no organization, no leader, no taking account of who belongs to the group and who does not. Other groups have recognized leaders and are definitely organized bands.

Flock and herd psychology. Flock and herd animals are supposed to be *imitative* and *suggestible*. If one of a school of fish darting through the water turns, the others imitate

it and also turn. If one of a flock of circling birds (starlings, pigeons, killdeer) wheels, the others wheel also. The one that turns first is for the moment the leader. The flock is kept together by its members' imitating each other's movements.

Examples of suggestibility are numerous among the herbivorous flock and herd animals. If one runs as though it had learned of danger, others will run. At the call of a sentinel, all are off. The animal does not act on its own knowledge, but accepts from another the suggestion for action. The suggestibility and imitativeness of flock and herd animals cause them to act in unison and keep the band together without compulsion. Sheep will keep close to one of their number that wears a bell and if one of a flock goes through a gate or over a fence the others are likely to follow.

Herd organization. The herd, among herbivorous animals, is organized for escape and defense. Its advantages are not connected with food getting but with the avoidance of enemies and in some cases the repulse of enemy attacks. Posting of sentinels is common in a herd and alertness and caution rather than strength and boldness are the qualities most needed in a leader. In the herd a younger animal is never allowed to command, and often an old female that has learned through experience the mishaps of taking chances has the head position.

In some flocks and herds there is equality of social rank among the ordinary members. In others there is social ranking as in packs. In herds of cattle each animal knows its rank with respect to others, and if a forkful of hay is thrown out in a barnyard one cow may drive another away from it. In a band of horses, too, there is a degree of dominance and subjection; and hens exemplify the "pecking order of society" in which each individual knows which other ones it may safely peck and which ones it must without resentment allow to peck it. Pigs are more interested in food than in social position, and a pig will make an active effort to monopolize a food supply. If milk is poured in the end of a trough one pig may climb in and lie lengthwise of the trough to prevent the milk from running down to the others, and pigs will do this when for weeks they have been provided two or three



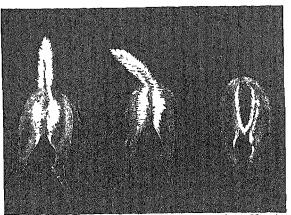
Fish and Wildlife Service

Bison on a government reserve. A large herd is made up of many smaller groups, each with its own leader.

times a day with an abundance of food for all. Any member of the group may do this and the others meet the situation not by biting the monopolist and trying to injure him, but by attempting to throw him out of the way.

The great cause of strife among most species of herd animals is the attempt of each male during the breeding season to gather a harem about him and drive other males away from the females he has collected. Of course only the stronger males can do this, and to decide which ones are the stronger requires much fierce fighting. The advantage of this arrangement from the point of view of the race is that it is a kind of natural culling by which in each generation the weaker males are eliminated from the breeding stock. In some species (e.g., horses, walruses) a male keeps his band with him throughout the year, and in these cases the younger animals form a part of it. In other species (elk, wild sheep, elephants) the bands break up at the end of the breeding season. When the young are born, the males that fought each other so fiercely a short time before may leave the females and young animals and form separate bachelor groups.

Herd signals. The commands of the leader or the warning of the sentinel or of any member of the herd that becomes aware of danger are passed on in various ways. There may be a call, such as is made by hens when a hawk is sighted. In an elephant herd there seems to be a signal system, perhaps through the waving of trunks or the flapping of ears, for if an elephant herd becomes aware of the presence of a hunter it will quickly retire



H. M. Laing, courtesy Nature Magazine

Herd animals often notify each other of the approach of danger. The illustration shows the alarm signal of the white-tailed (Virginia) deer.

with such silence that the hunter may not know what is taking place.

A surprising number of animals have scent glands from which odors are emitted as a danger signal, and the pronghorn antelope that was formerly so abundant on our

Western plains has a combined sight and scent system that is unique. This animal has a patch of long white hair on each hip near the base of the tail. Ordinarily the hairs lie flat, but if danger is discovered the hairs rise in a great fluffy circle and at the same time a scent is discharged from a gland in the center of each white patch. In a herd, which was sometimes very large, the alarm could thus be passed along without a sound.

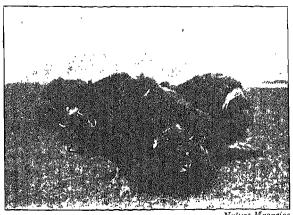
Herd defense. The antelope is the swiftest American wild animal and its defense is flight. It can run both faster and farther than a coyote or a wolf and when danger threatens it trusts to its speed. Other herd animals combine for defense, and of them all the musk ox of Arctic North America is in this respect the most skilled.

When a wolf pack comes near a musk-ox herd the older animals arrange themselves in a circle with their heads out and the young within the circle. If a wolf approaches too closely a musk ox may charge with its horns, but it never follows far enough to be cut off or to break the circle. According to the Arctic explorer, Vilhjalmur Stefansson, this defense is so effective that the wolves know they cannot penetrate it. They will pass by in sight of a

band of musk oxen without even causing them to fall into their defensive formation. A single wolf could easily hamstring a lone musk ox and make it its prey, but the combined resources of the herd are adequate for the defense of its members, both weak and strong.

The great herds of thousands of bison that formerly covered our prairies and plains were made up of smaller bands, each led by a great-grandmother, and if a wolf attacked a calf older members of the herd did not hesitate to come to the rescue. Like

many other ungulates they used both their horns and hoofs, and a wolf that entered a contest with a bison group was likely to be trampled to death in a short time. happens with so many herd animals, there were old bison males



Nature Manazine

A small band of musk oxen with heads out to the enemy.

that were driven out of the herd and lived solitary. These fell victims to wolf packs. While they defended themselves in front they were liable to attack from behind. The cooperative defense of the herd is the necessary answer to the coöperative attack of the pack.

Intelligence and instinct. In the great antelope herds of East Africa an individual member seems to do little to insure its safety except to act at times as sentinel and follow the leader. On our Western plains bison hunters used to shoot first the leader of the herd, and without the signal from her the others often made no effort to escape. The average herd animal obeys the signal and follows the leader and makes little use of its intelligence. There can be no doubt that the general outline of the herd life followed by each species is rooted in instinct. The sure proof of this is that herd customs are inherited and practiced without being learned.

If you see a flock of crows feeding in a field you will find one acting as sentinel. The posting of a sentinel would appear to be an act of real intelligence, but students of animal behavior are inclined to regard the taking a place as sentinel as a purely instinctive act. If a sentinel crow flies down, another without coercion or suggestion from others takes the watchman's place. Seemingly a crow has a positive tropism toward a vacant watchman's post.

Conduct within a herd. Generally speaking, as a herd pastures or browses there is little strife over food. Whether there is peace or fighting within it depends on the temperament and nature of the animals composing it and their attitudes toward each other. Dr. W. T. Hornaday reported that after long watching of wild herds of Indian elephants he had yet to see a single act of impatience or irritation among them. Cattle, in contrast, without apparent cause will dig at each other with their horns, and one horse may keep biting and kicking at another. One of the herds in which there is the most ceaseless strife is that of the guanaco, the wild ancestor of the llama. It is of a mild, placid appearance, with soft, lustrous eyes, but either wild or in captivity. like its distant relative the camel, it is most ill-natured and quarrelsome. The young and surplus males live in herds by themselves and of their conduct one explorer of the southern tip of South America wrote:

"A pair of wild guanacos can often be seen in furious combat, biting and tearing at each other and rolling over and over on the ground, uttering their gurgling, bubbling cries of rage. Of a pair so engaged, I shot one whose tail had been bitten off in the encounter. In confinement the guanaco charges with his chest and rears up on his hind legs to strike with his fore feet — besides biting, and spitting up the contents of his stomach."

An interesting suggestion in connection with the pack and the herd animals is that the animals in which the pack and the herd instinct is strongest are the ones that man is best able to rule and attach to himself. The theory is that the dog and the horse accept man as the pack or the herd leader. The human family with which the dog lives is his pack and he obeys his master as he would obey the leader of a pack. When a cat goes hunting it goes alone, and when it lives with man it does so as an individualist and on its own terms.



A troop of howler monkeys in their native habitat. A life like this is very different from that of a ground animal.

PROBLEM FIVE

How Are Monkey and Ape Societies Organized?

The monkeys and the apes live in bands that move about over a definite forest range. They lay up no food stores, but live on what they can find from day to day. The troop is a social rather than an economic unit. Within it each individual forages for himself.

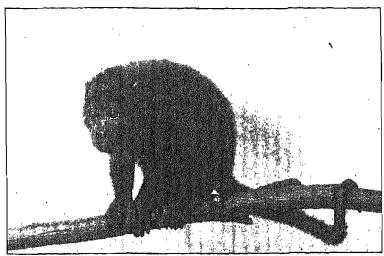
It is interesting to note that although the monkeys and the apes have more active and curious minds than any of the other animals we have studied and although the apes excel all other animals except man in mental power, they do not use their minds to improve their living conditions. Chimpanzees live as primitively as rabbits and more primitively than squirrels. In

captivity they show their intelligence by what they learn and the problems they solve, but in the wild they seem to have no impulse to apply their minds to the improvement of their physical lot.

THE MONKEYS

The monkeys are gypsies of the woods, here today and gone tomorrow. In the bands of most of the smaller species the males and females are not paired. This, along with the ceaseless wandering, makes impossible any family life comparable to that among the beavers. The mothers carry the babies along and care for them, but otherwise each monkey in a troop lives for itself.

Life in a band. As a monkey band moves through a forest its members feed on tender vegetation and the fruits of palms, figs, and other tropical trees. They rob the nests of birds, catch lizards, and pick up any insects that come in their way. The howler monkey bands of tropical America have been carefully studied and in the wild the members of these bands seem very peaceably inclined toward each other. In the troops of some



New York Zool. Society

A howler monkey. In addition to four grasping hands the monkeys of the New World have prehensile tails by which they can hold and hang. other species there is much squabbling and fussing. There is meddlesomeness, dominance and subjection, and among some species much bullying of the weak. The stronger ones grab from the weaker any articles they want. They run the weaker out of the choicer sleeping places. They love power for its own sake and they are extremely jealous of their social position and rank. When a monkey is punished by a keeper or by a stronger monkey he very commonly passes the insult on by beating up one weaker than himself.

A scientist kept a dominant monkey and a subordinate one in a cage together and noted their actions when food was introduced. The dominant one took it first 117 out of 131 times. When two that were so nearly equal in strength and aggressiveness that neither one could master the other were put in a cage together, their existence was one long quarrel. They could not settle down on a basis of equality, and they lacked that very desirable social trait of being able to attend to their own affairs and let others alone.

Advantages of the troop. To a monkey there are two distinct advantages in troop life. The first is that it satisfies the gregarious instinct, which is so highly developed in monkeys that one alone is miserable. An old proverb runs, "Better is contention than loneliness," and with this a monkey would probably agree. There is such a thing as enjoying a good fight, and in animals with the instinct for social ranking there is perhaps not much unhappiness in holding a lower place. It is natural for these animals to look up as well as down.

A second advantage of the band is that the members can give warning to each other of a climbing night enemy (leopard, jaguar, snake) which may find them when they are asleep, and that in an attack they help each other as much as they can. The smaller monkeys can do nothing but annoy a large animal, but in trees they are sure of themselves, they are quick, and they are bold in approaching and nipping at an animal much larger than themselves. There are some Old World species that weigh 40 or 50 pounds, and a band of these is rather formidable.



A colony of Hamadryad baboons in a London zoological garden. The native home of this species is northern Africa.

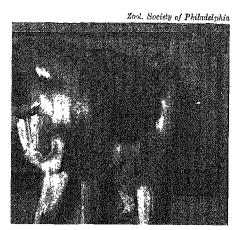
The baboons. These great African monkeys can climb, but they spend most of their time on the ground. They go in troops, turning over stones, logs, and leaves as they search for insects, scorpions, worms, lizards, small snakes, eggs, fruits, seeds, tender vegetation, and other foods. They tend to live in the hills, from which they descend to forage over the low-lands and to rob cultivated fields. They are dog-like in appearance and are exceedingly strong. An adult male can easily handle a large dog and they are not only brave but very irritable.

The baboons are credited with having the best-organized of all animal troops. They go in bands of forty to one hundred. There is a leader, and within the troop each of the stronger adult males gathers about him a number of wives. The little ones go with their mothers and the surplus males attach themselves as "bachelors" to these family groups within the band. The head of this smaller group holds his place only by his fighting powers

and at any time he is likely to be deposed from the headship of it and made to take a bachelor's place.

When a baboon troop goes on the march, there is a vanguard and a rearguard of old males, with the females and the younger ones in the center of the company. The mothers are kind to their babies and the husbands and wives seem to get along rather well if the wives do exactly as they are told. Among other members of the troop there are constant disagreements: if a young one comes within reach of an old one he receives a slap; two half-grown males will try to get the same piece of tender vegetation at once, and in an instant they will be in fierce combat, "rolling on the ground, barking and biting and fighting like young devils." They sleep in trees or in rocky strongholds. If it rains at night there will be an uproar caused by the stronger ones' routing the others out of the drier sleeping places. The word "selfish" very accurately describes the nature of a baboon. He takes for himself.

Yet the larger species of baboons are the very epitome of courage, and where the welfare of the troop is concerned they are quite capable of unselfish acts. One hunter writes of his dogs' pursuing a baboon troop, when in the retreat of the baboons to the hills a young one climbed a high rock and was cut off. When the leader discovered the situation he went to the rescue, drove off the dogs, and brought the youngster back with him.



The other males stood by and doubtless would have helped the leader if this had been necessary. Another writer tells of an occasion when a number of baboons were sitting in the edge of a wood and a young leopard was dis-

A mandrill. The home of this large baboon is in the forests of western tropical Africa.

covered creeping toward them in the grass. Without a moment's hesitation one baboon mother handed her baby to another and went to meet him. She had plenty of time to escape, but she risked her life against the common foe and was badly cut on the side before the males reached her and put the leopard to flight. In courage no animal excels the baboon, and pound for pound few animals equal it in fighting power. The males have a way of charging together that hunters fear. They unite the defensive skill of the herd with the mass attack of the pack, and no other animal except man understands this combination.

"He has the defects of his qualities" is a French proverb. We may apply it to the baboon. When a leopard attacks the band it is fine to have a bunch of fierce, dominant, courageous fighting males to go out and drive him off. Living with these heroes after the danger is over is another matter. In courage and in loyalty to his band we must hold the baboon in the highest esteem. His troop qualities as they relate to the outside world are excellent. In good nature, kindness, fairness, and other traits that are needed to make a good citizen within the troop he is sadly lacking. The natural consequences follow. The baboon has the best troop of any animal and one of the most unpleasant ones in which to live.

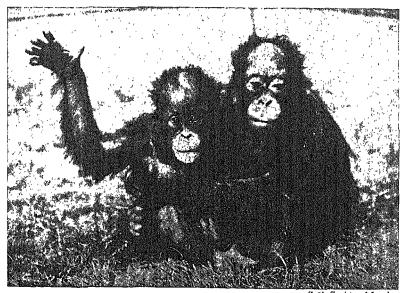
THE ANTHROPOID APES

The anthropoid apes include the gibbon, the orang, the chimpanzee, and the gorilla. They are far more highly socialized and more intelligent than the smaller monkeys. In them we find the nearest approach to the human body, brain, and mind. The gibbon and the orang are tree dwellers. The chimpanzee and the gorilla climb with fair skill, but they spend much of their time on the ground. All these apes live in smaller groups than do the baboons. The gibbons weigh only 10 or 15 pounds. The orangs and chimpanzees are man-size, weighing from 125 to 200 pounds. The weight of the gorilla varies from 250 to 600 pounds. The great apes reach maturity somewhat more quickly than man and are correspondingly shorter-lived.

The gibbons. The gibbons are slender, long-armed apes that are highly specialized for arboreal life. They live in bands in the forests of tropical Asia and the Indian Archipelago. A group of them can rush like a wind through a forest, swinging by their arms from bough to bough. Gaps of 20 or 25 feet are passed over without difficulty and a gibbon seems able to decide instantly where its next handhold will be. They feed on fruits, buds, leaves, and birds' eggs and other animal food that they can find.

The gibbons seem to live harmoniously with each other, but they have tremendous voices and love to make the forest ring with a chorus of high-pitched calls. In captivity they are friendly and obedient to man.

The orang. The orangutan is found only in thick-forested regions. A full-grown male stands about 4 or $4\frac{1}{2}$ feet high, but as in the other apes, the hind limbs are short and the orang is heavier than this height would indicate. It sometimes walks awkwardly on the sides of its feet, using its arms as crutches.



Zool, Society of London

Greetings from a pair of young orangutans.

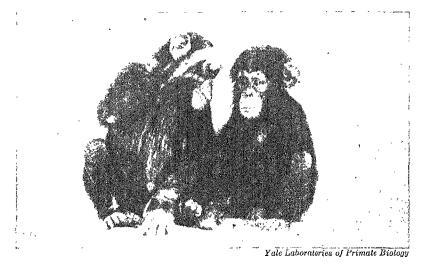
In the trees it usually swings along, hanging to the branches, but it may walk along a limb or climb about as a human being does in a tree. Its food is fruits and leaves, which it gathers without descending to the ground. It breaks off branches and builds for itself a sleeping platform or nest in the heart of a tree, where it is sheltered from the wind. In contrast with the gibbon, the orang is a silent and unsociable animal.

The orang lives in families — a couple with their children. When the young mature they choose mates and set up households of their own. In orang society more than in that of the other apes or monkeys the family rather than a larger group is the social unit. The young of the orang are playful and easily tamed. They seem to vary much in intelligence and in disposition.

Just how male orangutans get into fights is not known, but evidently some of them do, for they carry the scars of battle. Like the other apes, they fight by biting the opponent's face or its hands. Of thirty-nine specimens taken for museums by Dr. W. T. Hornaday in Borneo, five had lost fingers or pieces of their lips. One had lost both middle fingers; three toes and the tip of another finger were gone; each lip had a big notch in it; and his back had been hurt. In captivity a big, strong orang is inclined to be rough and boisterous with his cage mate, but not in an ill-natured way.

The chimpanzee. The chimpanzee is polygamous and lives in small bands that are headed by a large male. It spends much of its time on the ground and usually walks on all fours. Its chief food is fruits, but it eats other foods also. Like all the apes, it is very strong. A young female in the New York Zoölogical Garden seized a rope attached to a dynamometer and with one hand gave a pull that sent the needle to over 1300 pounds. She weighed only about 120 pounds, and good heavyweight college athletes cannot pull more than 700 or 800 pounds; so it was decided that a chimpanzee in proportion to its weight is about three times as strong as man.

In their native habitat chimpanzees wander about in the woods in small groups seeking food, or one may make an excursion alone.



A secret between young chimpanzees.

A band is usually composed of a head old male, several wives, and the children, which stay with the parents until they are eight or nine years of age. In some bands there is more than one adult male, but always one is head. At night they build tree nests and sleep where they happen to be.

In chimpanzees the dominance and subordination instinct is present, and where a number are kept together, without much fighting each one soon achieves a definite rank. They are quick-tempered and resist unfairness, which shows that they know what fairness is. When well treated they are friendly to man, and they are the most agreeable of the large apes. Old ones sometimes are dangerous, but it is reported that in the wild state there is not much fighting among them. Different bands do not carry on wars with each other.

The gorilla. The gorilla is the giant of the primates. Its strength is prodigious. An old male of the largest species (the mountain gorilla) weighs from 400 to 600 pounds; one was killed that had an estimated weight of between 600 and 700 pounds. The gorilla is a vegetarian, feeding on fruits and on shoots. It has longer arms than the chimpanzee and lives more on the

Nature Magazine

ground. It usually walks in a swinging way on all fours, setting the knuckles of its hands on the ground. Gorillas build sleeping platforms by pulling together the tops of saplings and placing branches of trees on top of them, or they may build a platform in the lower branches of a tree or make a bed on the ground.

The gorilla is much more sullen and unresponsive than the chimpanzee, but the young can be tamed and in intelligence they are practically equal to the chimpanzee. Of the group life of the gorilla little is known, for it is a rare animal and a shy one, and until recently attempts to keep it in captivity met with little success. The relationships between the members of a gorilla band are probably much the same as are found in a band of chimpanzees. In both there is rule from above, but it is not harsh as in troops of baboons.

Mentality of apes. The apes display an order of intelligence quite beyond that of any animal not in the primate group. The chimpanzee has been most studied and when young

it is the most tractable, but the orang and gorilla may equal it in mental power.

A young chimpanzee readily learns to ride a tricycle. It loves to coast along with children and will draw its sled uphill to ride down again. It quickly learns to swing along on roller skates and to field a ball expertly. They are natural actors and love to perform. A chimpanzee will use a hammer to drive

The gorilla, the giant of the primates. The largest adult males weigh up to 600 pounds



A walking lesson for a baby chimpanzee.

nails and will select a key from a ring and open a locked box. One in the London Zoölogical Garden would hand its keeper any number of straws asked for up to five. If a banana is placed in a cage beyond reach and a stick is provided, the chimpanzee will use the stick to draw the banana to where it can grasp it with the hand. One chimpanzee, without instruction, fitted to-

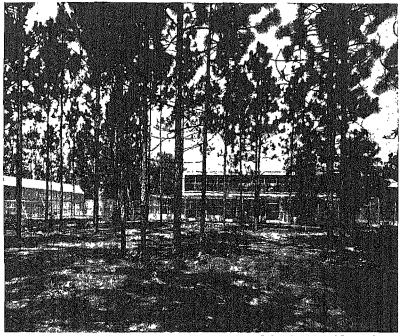
gether two pieces of bamboo to form a stick long enough to bring the banana within arm's reach. Chimpanzees learn the meanings of many words and commands, and their mentality is supposed to equal that of a normal child of two to three years.

Emotional and instinctive equipment. Emotionally and in many of its instincts the chimpanzee seems to be much like ourselves. The young play and tease each other. A young female in the New York Zoölogical Garden would carry straw and make herself a bed on a shelf, and her male companion delighted in rushing in about the time she had it finished and scattering the straw about. A chimpanzee mother pets her baby and chimpanzees kiss their friends. They are sociable and dread being left alone. If one is sick the others are sympathetic and will come and caress it. They are quick to take advantage of any weakness or timidity and they boss each other rather forcibly. One is always head of a group, and both the crowd and the caste spirit in them is strong. The crowd will come to the assistance of any member of the group against an outsider and it will help the leader against one of lower rank. One group of chimpanzees

would take the part of the keeper against their own leader, evidently considering the keeper to be of still higher social rank.

An exception to the rule of not training the young is found in the chimpanzee and perhaps in some of the other apes. A chimpanzee mother will sit with her baby between her legs and help it to stand by holding it up by the hands. She will place it on the wire of a cage and hold it as it learns to climb. A chimpanzee mother seems to try to show her baby how to do things much as human parents try to train their children in the things they wish them to learn.

A chimpanzee colony. At Orange Park, Florida, Yale University has a flourishing colony of chimpanzees in which young babies have been born and reared. Apes are being reared elsewhere also under conditions that are as nearly natural as pos-

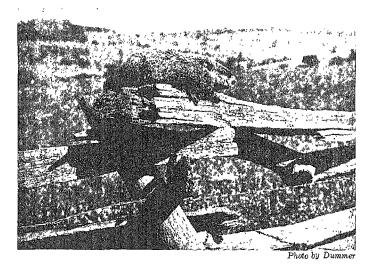


Yale Laboratories of Primate Biology

Living quarters of the chimpanzees in the colony at Orange Park, Florida.

sible, and we shall soon know more of these interesting animals. Most of what we know about the structure and physiology of the human body has been learned by a study of other forms, and psychologists are studying the behavior, the intelligence, and the instinctive and emotional life of the apes with the hope that what they learn may help us understand ourselves. You will find the accounts of the behavior of these great primates most interesting. In many ways they are amusing and entertaining but their behavior is also very instructive.

The monkeys and apes are a diversified assemblage and there is much variety in their ways of living. Yet certain social traits are characteristic of the group. They are gregarious, but at the same time they are individualistic. They live in bands, but as in a flock or a herd each individual forages for himself. They make no provision for the future. They are jealous and contend bitterly for place and power, and in their troops and bands a caste system arises that gives to each individual the social rank he achieves. The monkeys and apes lack entirely the communal instincts of the bee. In their society the equality and freedom of the beaver colony are not found.



Artomys monax, who prefers his own society to that of others.

ORIGIN OF SOCIAL WAYS

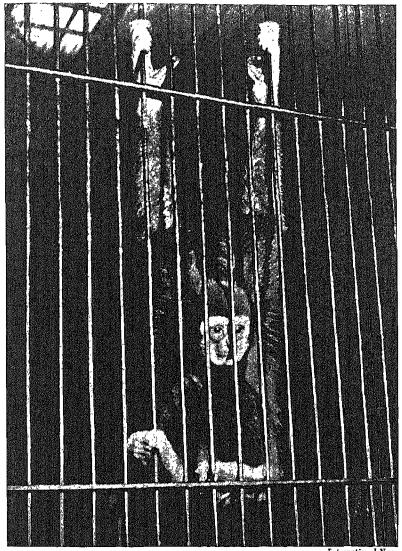
Place some frog eggs in an aquarium and care for them. They will go through a certain course of development and become frogs. Turn them loose after they are grown and they will act like frogs and take up the frog way of life. It is natural for frog eggs to develop into frogs instead of into some other kind of animal. It is natural for frogs to act and live as frogs do. Each animal species has its own unlearned way of living. It inherits the instinct to live the way it does as definitely as it inherits its organs and body form. One species does not imitate another, nor is there compulsion to force the young into the ways of their parents.

The higher animals as well as the lower ones inherit a behavior pattern. Within a certain range they adapt their actions to their conditions, but variations in their behavior are only modifications of the inherited fundamental living plan. Any social organization found among animals is not planned or passed on through experience. In each generation it springs anew from the instincts of the members of the group.

UNIT COMPREHENSION TEST

- A. How many kinds of bees are there in a hive? How many workers are usually in a hive? From what do bees make honey? How do they make beeswax? What is the duty of the queen? How is sex determined in the bee? How are young bees reared and fed? What special diet does a developing queen receive? Mention some adaptations of structure found in the bee. How do they concentrate the honey? What bees administer the affairs of the hive? Tell of the social instincts and ethics of the bee.
- B. Describe a beaver. Why is it considered so remarkable an animal? Describe the method of building a dam. How is a greater food supply reached with safety? Describe a beaver lodge. Tell of beaver family life. How is food stored for winter use? How does the beaver escape its enemies? What relations exist among the members of a beaver colony?
- C. Describe the organization of a pack. What are the strength and the weakness of the pack? Account for pack organization in terms of the instincts of the pack members. Mention some temporary hunting associations. Contrast pack animals with bees and beavers.
- D. Mention some animals that live in flocks and herds. Give two psychological characteristics these animals are supposed to have. Tell of the organization of herds and the relations of herd members. What is the great cause of strife among herd animals? Mention some of the ways danger signals are passed among herd animals. Give some examples of herd defense. What evidence is there that herd actions are based chiefly on instinct?
- E. Describe the way monkeys live. What are the relations of the members within a monkey troop? What advantage is there in the troop? On what do baboons feed? Describe the organization of a baboon band. Tell of the character of the baboon. Name the four kinds of anthropoid apes. About what is the weight of each kind? Describe the gibbons and the way they live. Tell of the living habits and family life of the orang. How is a chimpanzee band organized? Give an account of an experiment which showed the great strength of a chimpanzee. Tell of the daily life and of the disposition of the chimpanzee. Describe the gorilla. How does it walk? On what does it feed? What structures do apes build? Tell of some of the things chimpanzees can be trained to do. Mention some of their instinctive acts. Where in our country is there a chimpanzee colony? Contrast monkey and ape society with that of bees and beavers.

SUGGESTED ACTIVITIES AND APPLICATIONS



International News

1. This animal weighs about 12 pounds and is the world's champion trapeze performer. It has no tail and when it stands upright its arms reach the ground. What animal is it? Where does it live?

- 2. Observe the moving about of a flock of domestic ducks or geese. Does the flock have a leader? How is the direction of movement of the flock decided?
- 3. Does a flock of sheep or a herd of cattle have a leader as it grazes over a pasture?
 - 4. Observe the actions of a school of minnows.
- 5. Arrange an ant colony in the schoolroom and study the activities of its members.
- 6. Would a statement that different kinds of animals are as distinctive in their behavior as in their physical form be true?
- 7. Read one or more of the books listed below and write a report on the behavior in its native habitat of one of the animals described.

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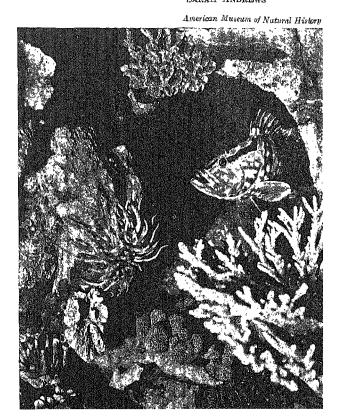
unit 18

TYPES OF WATER ANIMALS

Land plants and land animals are interesting upward biological shoots, but the great trunk and roots of life are in the sea.

"Water animals may stand plant-like and wait for currents and waves to bring them food. They may subsist by straining microorganisms from the water in which they are bathed. Ways of life are open to them that are not possible to land animals and there is a diversity among them such as is not found in the animals of the land."

SARAH ANDREWS



THE MULTITUDE OF WATER ANIMALS

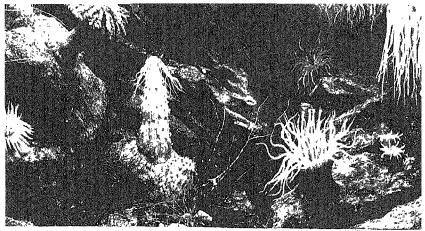
OUESTION FOR CLASS DISCUSSION

What is the essential difference between a water animal and a land animal?

OF ALL the animal phyla only two (the arthropods and vertebrates) are of importance on the land. Most of the other phyla are represented only by aquatic forms. The typical animal is a water animal; the land animal is an unusual and specialized type. To have anything like a complete view of the animal world, it is necessary to know something of the great assemblage of water forms. In this unit we shall therefore take up some of the more important types of water animals that we have not yet studied. The purpose of the unit is to provide a wider base for the biological observation and thinking you will doubtless be carrying on years after the completion of this course.

Problems in Unit 18

- 1 What animals are included among the coelenterates and how do they live?
- 2 What is the plan of the echinoderm body and where and how do the echinoderms live?
- 3 How can the success of the bivalve and snail groups of mollusks be explained?
- 4 What are the important groups and characteristics of the cephalopods?
- 5 What are the characteristics and adaptations of the crustacea?
- 6 What are some of the other important kinds of water animals?



Carnegie Museun

A group of sea anemones. Like all the other coelenterates, they have tentacles that seize small organisms and feed them into the mouth.

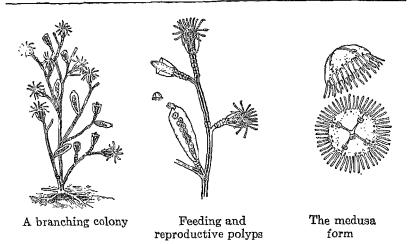
PROBLEM ONE

What Animals Are Included among the Coelenterates and How Do They Live?

The hydra is a coelenterate and it has a great group of relatives that live in the sea. The group includes such animals as the hydroids, jellyfishes, corals, and sea anemones. They are all radiate animals, built about a mouth. Perhaps it will be helpful for you to review the description given of Hydra (page 301) in connection with this study of the coelenterate group. All of the coelenterates are able to seize and use for food animals larger than they would otherwise be able to handle because they paralyze their victims with their stinging cells.

THE HYDROIDS

The word "hydroid" means hydra-like, but most hydroids are more like a colony of hydras than a single one. They look like branching plants, and they grow attached to piles, rocks, seaweeds, or the ocean floor. A description of *Obelia*, one of the common kinds found on our Atlantic coast, will give an idea of what the members of the group are like.



Obelia, a representative hydroid. The medusae produce eggs and sperms from which the colonial form grows.

Obelia. A young Obelia starts much like Hydra, but it buds profusely and the buds remain attached as branches instead of being cut off and set free as in Hydra. Each branch enlarges and forms at its tip a *polyp*, which is itself like a little animal. In this way Obelia grows until it is like a branching plant with a small animal on the end of each twig. A single Obelia may have hundreds or even thousands of polyps on the ends of its branches. A hollow runs through the stalk and the branches, connecting all the body parts.

Most of the polyps, like Hydra, have a mouth with tentacles about it. As in Hydra, there are nematocysts on the tentacles and there are flagellated and gland cells inside each polyp and lining the hollow of the stalk. The tentacles wave and writhe about and if a small animal comes within their reach it is stung into inactivity and fed into the mouth. When a polyp captures and digests a small animal it doubtless gets more nourishment from it than a polyp on a distant branch obtains, but food is passed from one part of the Obelia body to another through the hollow stalk.

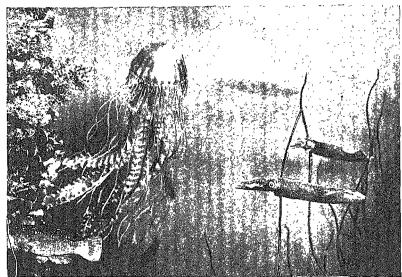
The Obelia is covered with a tough, horny layer of chitin that stiffens and protects it. It is the same material that covers the body of an insect. The stalk has a chitinous covering and each polyp rests in a transparent chitinous cup.

The medusa generation. Now comes the surprising part of the Obelia story. Some polyps do not develop tentacles, but grow into ovoid bodies which produce flat buds. These break loose and swim away as little jellyfishes! One of the jellyfishes is shaped like a small umbrella with a row of tentacles around the edge. Each one is called a medusa (plural, medusae). In Greek legend Medusa was a woman-faced monster with snakes for hair and the early naturalists imagined that the tentacles hanging down from the jellyfish resembled snaky locks.

In general plan a medusa is like a polyp, but the mouth is inside the umbrella and the medusa is a better-organized animal. There is a nerve ring at the base of the tentacles, and the umbrella, or body, has cells in it that are distinct muscle fibers. As the medusa lies in the water the body wall contracts rhythmically, forcing the water out and driving the animal backward. The muscle contractions are regulated by the nerve ring.

Reproduction by medusa generation. The medusae are the sexual generation of the hydroid and they are differentiated into male and female animals. In some there are male sex organs, or testes, that produce sperms. Other individuals have ovaries, or female sex organs, that produce eggs. The eggs and sperms are set free in the water and after fertilization the egg develops into the plant-like form of Obelia again. In Obelia, therefore, we have an alternation of generations — the asexual polyp generation and the medusa generation. The medusae by swimming spread the organism to new places, and the fertilization of the eggs in this generation gives opportunity for the vigor of the protoplasm to be renewed.

Obelia and many other kinds of hydroids similar to it grow like mosses along coasts. They are attached to seaweeds, corals, shells, stones, or any other support. Some kinds of crabs and marine snails feed on them, and eating a part of a hydroid colony does not kill it. As grass cropped by a cow or a sheep springs up again, so a hydroid colony can renew itself by the growth and



American Museum of Natural History

Jellyfishes are surprisingly abundant both in shore waters and in the open sea. The two animals at the right are squids.

branching of a remnant that may be left. In many of the lower animal forms this plant-like ability to regenerate lost parts is a distinct aid to survival.

THE TRUE JELLYFISHES

The true jellyfishes are much like the medusae of the hydroids, but they may be from an inch up to 6 or 7 feet in diameter. They are flatter than the medusae and differ from them in having notches (usually eight) in the margin of the umbrella. They produce eggs and sperms, and a fertilized egg grows into a little hydra-like polyp which by budding gives rise to the jellyfish generation. As in the hydroids, there is in most jellyfishes an alternation of generations, but the polyp generation is small.

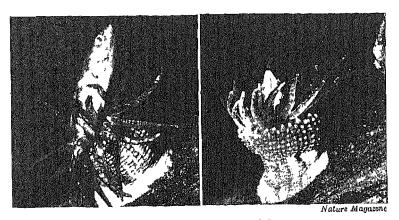
The jellyfish body. In some of the jellyfishes there is a great thickening of the mesoglea (middle body layer, page 305). It is a jelly-like material, mostly water, but it gives to some of the jellyfishes considerable size and weight. The largest ones in the warmer seas weigh nearly 100 pounds and the largest in the

polar seas weigh up to a half ton. Some have long trailing tentacles of great stinging power. With these they paralyze small fishes and other small animals which are used for food.

As in the Obelia medusa, there is in a jellyfish a nerve ring at the base of the tentacles, and on the ring at each notch in the umbrella is a ganglion, or collection of nerve cells. This gives the jellyfish eight little brains. If one or two or three or any number up to seven of these are removed, the rhythmic contractions of the body wall are kept up. If all are removed, the contractions cease. The animal is paralyzed and lies still. It would seem that the stimulus which causes the contraction originates in the nerve cells and not in the muscle cells. In a euglena or paramecium the protoplasm of the cell has the power to contract without a nervous system to set it off. The muscle cells of the jellyfish (also of higher animals) have been specialized until they have lost their spontaneity — the power to act spontaneously, or of themselves.

SEA ANEMONES AND CORALS

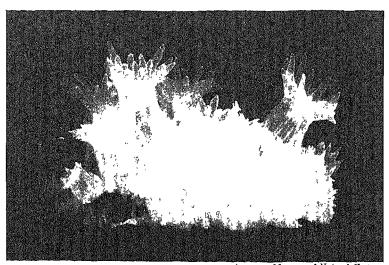
In these coelenterates there is only the polyp generation. There is no medusa, or free-swimming form. The polyps are much larger than in the hydroids. A sea anemone is a giant solitary polyp. Most of the corals are colonial and secrete a



A sea anemone eating a fish,

calcareous skeleton on which they rest. Like all the other coelenterates, the sea anemones and corals have tentacles and stinging cells.

Sea anemones. A sea anemone has a large number of tentacles which when extended float out in the water like the fringed petals of a flower. One common on our Eastern coast is, when extended, perhaps an inch in diameter and 6 inches or more in length. It lives attached to rocks or other objects. Its food is young shrimps and prawns, tiny fishes, and other small animals that the tentacles sting and bring down into the mouth. It can move by crawling along on its base as the hydra does; and, like the hydra, when danger threatens it shortens itself into a ball. The body and nervous system are more complicated than in a simple polyp. Reproduction is by buds formed at the base of the animal, by longitudinal division of the animal's body, or by eggs and sperms. There are many species of sea anemones, but in general structure they are all alike. Some are brightly colored. The largest ones may be a foot across.



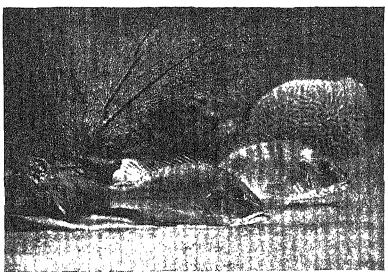
American Museum of Natural History

The fleshy or living part of a coral growth. It consists of a layer of living material over the skeleton with numerous polyps by which the organism feeds.



Shedd Aquarium

In the warmer seas corals grow so abundantly that their limestone skeletons form many islands and extensions of the land. At the right behind the fish is a portion of one of the branching tree corals.



Shedd Aquarium

At the right is a piece of brain coral, a kind often found on coral reefs. The flattened structures shown in this and in the illustration above are sea fans. They are members of the coral group.

The corals. The corals differ from other coelenterates in that as they grow they build up beneath themselves a deposit of calcium carbonate, or limestone. Over this the coral grows as a layer of living matter which at close intervals rises in polyps, each with a circle of tentacles and a mouth. Each polyp sits in a little cup which it builds beneath itself, while a sheet of living material connects the polyps and covers the spaces between the cups. New polyps are produced by buds around the bases of the old ones and in this way the growth spreads on and on.

Some corals grow in flat layers and some in rounded masses. Some build up a branching tree of limestone with the polyps living as a surface layer over it. In some, like the sea fans and the sea feathers, the skeleton is fine and the polyps are small. In other species the polyps may be several inches or even a foot across. A few corals live in temperate waters, but they are most abundant in the warmer seas. Here in shallow but clean water, some kinds build beds of limestone that form reefs and low islands. The Florida Keys, the Bahamas, and the Bermudas are coral islands. North of Australia for 1100 miles is a great barrier coral reef. Among the branches of corals and in the crevices between them, hosts of other sea animals make their home.

The coelenterates are an old group. Fossil corals are abundant far down in ancient rocks, and imprints of early Paleozoic jelly-fishes are found. The alternation of generations found in the hydroids and jellyfishes is unusual in the animal world, as is the colonial form of the hydroids and corals. Would you say that Obelia or a sheet of coral is one animal feeding through a hundred or a thousand mouths? Or is each polyp an animal united by a living connection with other animals? Does each polyp correspond to a leaf on a tree or to the whole tree? Is it an organ or an organism?

PROBLEM TWO

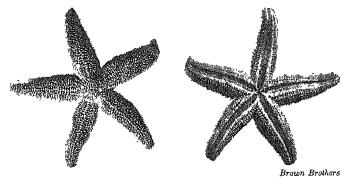
What Is the Plan of the Echinoderm Body and Where and How Do the Echinoderms Live?

The echinoderms too are radiate animals. The body is built around a mouth, and they do not have a head as the worms and all the higher animals have. They are found only in the sea. The starfishes, brittle stars, sea urchins, sea cucumbers, and crinoids are the principal echinoderm lines.

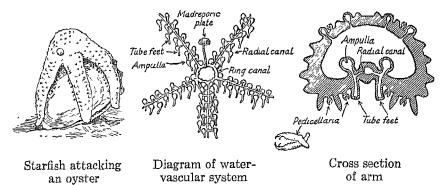
THE STARFISHES

The more common kinds of starfishes live in shallow ocean waters, clinging to rocks or piles or walking about on the bottom. They are strictly carnivorous, feeding on oysters, clams, worms, or other animals of a size that they can master. Starfishes are the rats of coastal waters, and at times swarms of them invade oyster beds and work great havoc.

Starfish body. The body of a starfish is flat and is extended out into five arms that can be bent and moved about. The skeleton encloses the soft organs and consists of limy plates held together by connective tissue. The mouth is on the underside in the middle of the central disk. There is a ring of nerve tissue around the mouth, and from the ring a nerve runs out to the tip of each arm. The stomach is a large pouch directly above



Views of the upper and lower surfaces of a starfish. The tube feet are set along the sides of the grooves on the lower surfaces of the arms.



The pedicellaria of the starfish are tiny nipper-like structures that are found over the body. By their opening and closing they are supposed to keep the animal free from small parasites.

the mouth. It opens into a very short intestine from which branches extend out into the arms. At the tip of each arm is an "eye." This is sensitive to light, but it has no lens and does not form an image as our eyes do. From its eyes the starfish can receive information as to light and darkness and the direction from which light comes, but it cannot "see" in the sense that its eyes give it a picture of the external world.

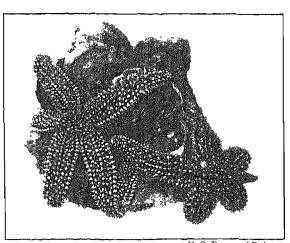
How a starfish walks. If you turn a starfish on its back you find on the lower side of each arm four rows of tube feet. These are filled with water and at the top of each foot is a muscular bulb that by contraction can put pressure on the water and shoot the foot out as a long, slender tube. When a starfish walks, it extends its feet in this way. A number of the feet stick by suction to whatever the animal is walking on and then the feet shorten and pull the animal along.

The tube feet of the starfish are a part of the water-vascular system, as is shown above. Except in the other echinoderms there is nothing like this water-vascular and foot system in the whole animal kingdom. Taken along with the flexible arms, the tube feet give the starfish a very fair substitute for hands and feet. The water-vascular system is connected with the water outside the animal's body, and to a degree it serves as a respiratory system.

How a starfish eats. The starfish opens an oyster by setting it up on edge, climbing astride it, taking hold of the shell on each side with its tube feet, and beginning to pull. At first the oyster is too strong for it, but the starfish sits quietly and keeps the pull on, and in fifteen or twenty minutes the shell begins to open. Instead of swallowing the oyster the starfish throws its stomach out of its mouth, wraps it about its dinner, and digests it. When it has finished, only the shells of the oyster remain. Small oysters and other small shellfish may be taken into the stomach without being opened, and the shells later thrown back out of the mouth.

For a cold-blooded, sluggish animal the starfish has a voracious appetite. One ate more than fifty clams in six days. In one year off the coast of Connecticut alone, they destroyed more than

\$600,000 worth of oysters in spite of the fact that 42,000 bushels of them were taken out of the beds and destroyed. They are caught by dragging over the oyster beds mops of fine cord to which the pedicellaria cling. Fortunately it has been found that the starfish can



U S Bureau of Fisheries

Starfishes feeding on small oysters. The one at the right has been mutilated and is growing new arms.

be destroyed without injury to the oysters by distributing quicklime over the oyster beds.

Reproduction. Reproduction in the starfish is by eggs and sperms that are discharged into the water. The animal becomes full-grown in about a year. As in many other of the lower animals, there is remarkable power of regeneration. If an arm

is cut off, a new one grows. If one arm is left on a small part of the disk, or body, a complete new animal will be produced. Oystermen formerly cut in two the starfish that they brought up, and threw them back into the water, but they found that instead of destroying the pests by doing this they multiplied them.

Memory in the starfish. If a starfish is placed on its back it uses its arms to turn itself over. In working with them Professor Jennings of Johns Hopkins University noticed that an individual would begin the movement with a certain arm; so he decided to do an experiment with them. He held down four of the arms, including the one that was usually used, so that the starfish would be compelled to start the turning over with the one free arm. After a time his starfishes learned to begin with this arm even when none of the arms were held. One that had had 180 lessons in 18 days remembered seven days later to begin in the new way. Young ones were easier to teach than old ones.

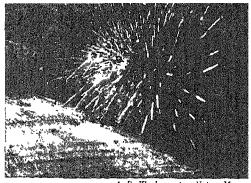
The brittle stars. The brittle stars are relatives of the starfish tribe that have slender, flexible, snake-like arms with no feet on them. They are called also snake stars and serpent stars. They swim by moving their arms in the water. Their food consists chiefly of small organisms that they scrape from seaweeds or capture with their flexible arms. They get the name "brittle stars" from the fact that the arms break off easily. If an arm is caught by an enemy, the brittle star leaves it behind and hurries away. There are some forms called "basket stars" in which the arms are branched.

OTHER ECHINODERMS

The other important echinoderms are the sea urchins, sea cucumbers, and crinoids. All of them have the water-vascular system and tube feet, but they are very diverse in their body forms. They are vegetarians or live on small organisms; they are not predators as the starfishes are.

Sea urchins. A sea urchin is fitted for defense rather than attack. It looks somewhat like a small, round, dark-colored

prickly cactus. It has no arms, but has five bands of tube feet running up the sides of its body. The mouth is armed with five bone-like teeth. It lives chiefly by eating seaweed or by swallowing mud or sand and digesting the organic matter in it. The spines are coarse and strong and



A B. Klugh, courtesy Nature Magazine

A sea urchin. It feeds on ooze and vegetable matter and is an animal fitted for defense.

each is movable on a little tubercle on which it sits. The feet can be thrust far out as slender tubes and the animal moves by the feet on its lower side. The spines help to keep it from tipping over and they are, of course, a great protection against other animals that might use the sea urchin for food. In the breeding season each individual contains a large mass of eggs or sperms. In Mediterranean countries at this season, large numbers of them are gathered for human food.

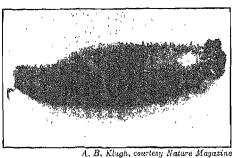
The sea urchin lives near rocky shores, but it has a much flattened relative called the sand dollar that lives on sandbanks. This has spines so fine that it has almost a velvety appearance.

Sea cucumbers. The sea cucumbers are built like a sea urchin laid on its side and stretched out lengthwise into the shape of a cucumber. Instead of being spiny they are covered with a leathery skin. They live near coasts, burrowing in sand or mud and pulling seaweeds over their bodies to hide themselves. The body walls are quite muscular and the animal moves by the tube feet and by contractions of the body. In some of the Pacific islands and in South China, sea cucumbers are used extensively as food. Some of those on the Great Barrier Reef of Australia are 2 feet or even a yard long.

Nourishment and protection. Most of the sea cucumbers are ooze eaters. One small form called the sea gherkin solves the food problem in an unusual way. About its mouth are branching tentacles that float out in the water like whiskers. Small

animals come to rest on these, and when enough little animals have collected on a tentacle it is bent around into the mouth and its load removed by pulling it through the closed lips. Thus the sea gherkin collects from the water a food supply.

The sea cucumber defends itself in a remarkable way. When an enemy attacks it, the body walls contract with such force



A sea cucumber. The hair-like projections are tube feet.

that the body is ruptured and a part or nearly all of the internal organs are shot out. The intestine, nervous system, and water-vascular system may all go and only a ring about the mouth remain. In some kinds the defense lies in the fact that the attacker may be satis-

fied with the feast that the thrown-off parts provide.

In other species called "cotton spinners" an additional defense is provided. In these kinds the ejected internal material swells and turns into sticky threads in which the enemy may become entangled. A lobster has been known to become hopelessly enmeshed in them.

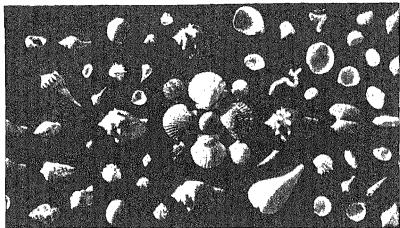
A sea cucumber has remarkable powers of regeneration and can soon grow a new set of internal parts. If as much as one twentieth of the fore part of the body remains, it renews itself without difficulty.

The crinoids. The crinoids have branched arms. A few kinds lead a free-swimming life, but most of them grow on stalks. Most of them live in water of moderate depth, but there are also shallow water forms and kinds that live on the ocean floor several miles beneath the surface. The stalk is fastened to the middle of the side away from the mouth so that the animal stands mouth side up. It holds its branching arms outspread and catches the particles of organic matter that settle down from above. Along

the center of each arm there is a groove down which cilia beat the food particles toward the mouth. Crinoids are not eaten by fishes because of the amount of mineral the skeleton contains.

The crinoids were very abundant in the ancient seas. They are the "stone lilies" of geology. Whole beds of limestone may be made up chiefly of their stems and arms. If we accept the time clock of geologists as being at all correct, we must believe that more than 600 million years ago crinoids were standing on the ocean floor with their flower-like arms outstretched to catch the diatoms and animal material that drifted down to them from above. Today, in the changeless cold and darkness of the ocean's depth, we find crinoids of practically the same kinds living in the same way.

The echinoderms are very different from any other animal group. There are about 5000 known species and they hold a really prominent place in ocean life. Most of them live exposed lives, and among them many interesting structures and adaptations for protection against enemies are found. The group is much more varied than our brief description of it suggests.



Nature Magazine

Mollusk shells from the beach at St. Petersburg, Florida. There were shells much like these on the beaches of 500 million years ago.

PROBLEM THREE

How Can the Success of the Bivalve and Snail Groups of Mollusks Be Explained?

The mollusks have been one of the most successful animal phyla in every age from the early Paleozoic until the present time. As you will see by consulting page 990, there are three main divisions of the phylum: the lamellibranchs, the gastropods, and the cephalopods. The lamellibranchs (bivalves) and the gastropods (snails) are our subject in this problem. How can we account for the success of such animals as the clam and the snail?

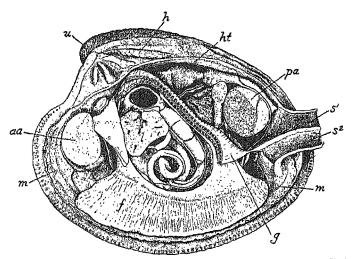
THE LAMELLIBRANCHS

The lamellibranchs get their name from their leaf-like gills. They are pale, limbless, headless, soft-bodied animals that have shells and get their food by straining it out of the water in a sponge-like way. Mussels, clams, oysters, scallops, and cockles are examples of the lamellibranchs. They are spoken of as the bivalve mollusks, or bivalves, because they have the shell in two parts. The largest of the bivalves is a great clam-like

animal found in the Pacific and Indian oceans. It reaches a length of 5 feet, and including the shell it may weigh 500 pounds.

The lamellibranch body. If you should examine a lamellibranch (clam, oyster) you would find that the soft body is wrapped in a whitish mantle that lines the shell on each side of the body. The shell is built of mineral matter (calcium carbonate) and horny material secreted by the mantle. As the animal grows in size the mantle keeps adding to the outer margin of the shell. The lines on the shell, like the rings in a tree, represent alternating periods of slow and of rapid growth. One or two strong muscles stretch across between the two sides of the shell and close it when danger threatens. You can see the places on clam or oyster shells where the muscles have been attached. An oyster is opened by cutting the muscle that draws the two sides of the shell together.

Within the mantle of a lamellibranch there are on each side two delicate leaf-like gills. There is a head end to the body but no head, the mouth being a mere pit. In most species of bivalve



Drawing by W. P. Hay (after model in Am. Mus. Nat. Hist.)

The common clam or qualog (Venus mercenaria), partly dissected: f, foot; g, gills, mainly cut away; m, mantle; s^1 and s^2 , upper and lower siphons; aa and pa, muscles which close the shell; ht, heart; h, hinge.

mollusks the body at the ventral edge (toward the opening of the shell) is prolonged into a muscular wedge-shaped foot. The oyster is footless and cannot move, but clams and some other bivalves can thrust the foot out of the partially opened shell and inch themselves slowly along.

A very important feature of the lamellibranch is the *siphon* at the rear end of the body. It is made by joining together the two sides of the mantle and has two openings in it. Water is drawn in through one opening of the siphon and is passed over the gills and then out through the other opening. In some species (long-necked clams) the siphon is greatly prolonged, so that when the animal is buried in mud it can still draw water through the siphon from above the surface of the mud.

How a lamellibranch gets food. The gills of a lamellibranch are porous like a grating, and they are food-gathering as well as respiratory organs. If you will examine under a microscope a small piece of a gill from a living clam or oyster, you will find that it is covered with long cilia that look like a forest of waving hairs. The cilia beat the water in one direction and this causes a flow of water down one side of the siphon, over and through the gills, and out through the other opening of the siphon. How efficient the cilia are as water circulators is shown by the fact that at summer temperature a medium-sized oyster may filter more than a barrel of water through its gills in a day.

As the water passes through the gills, any small food particles (algae, protozoa, bacteria, or small pieces of dead organic material) that may be in the water are strained out. This food material by the action of the cilia is worked to the top of the gills and then forward to the mouth. Sometimes when green algae are very abundant in the water, oysters have "green gills," and in the Chesapeake Bay region a one-celled red alga (*Haematococcus*) is sometimes so abundant that the oysters have "bloody gills."

In waters rich in organic materials or in which small forms of life are abundant, this method of food gathering is very effective and the lamellibranchs thrive amazingly. In some places oysters lie thick on the bottom; in other places sea mussels hang from the rocks so close together that they touch. There are thousands of kinds of mollusks of this group and some of them are important as human food. The kitchen middens — refuse heaps left by earlier men — of northwestern Europe and of our own Atlantic coast are in large part made of lamellibranch shells.

Success of lamellibranchs. The success of the lamellibranchs is unquestioned. To what is it to be attributed? Many factors enter into the success of any organism, but certainly an important factor in the success of the lamellibranchs is the protective shell. The lamellibranchs follow a sedentary and strictly defensive life and the shell is an armor against many animals that might prey on them.

A second factor in lamellibranch success is the method of getting food which in many locations gives them access to a rich supply without competition from other animals. The lamellibranchs in their food-gathering system have the advantage held by the unlike (page 90).

THE GASTROPODS, OR SNAILS

The snails have the shell in one piece, and usually twisted or coiled. There are many species in the group and they are found in salt water, in fresh water, and on land. They vary in size from the little "wheat grain" and "rice grain" ones to kinds that have shells 18 inches across. Snails are found uninterruptedly from 1600 feet below sea level to the snow line on mountain peaks.

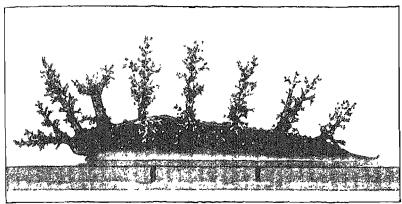
The snail body. The prominent parts of a snail's body are shown on page 573. There is a head, eyes that can be waved about on the ends of tentacles or stalks, and in some species other tentacles about the mouth. There is a single oval foot, which in many species closes the entrance when the animal withdraws into its shell. The body of the snail is twisted, and the mantle and gills on top of the body correspond to those on one side of a lamellibranch. Often the shell is referred to as the snail's house, but it is an armor rather than a house. The owner of the shell cannot move about in it, but must put out its foot to walk and its head to eat.

The gills of a water snail are feather-like, instead of being leaf-like as in the clams and their relatives. Instead of gills, the land snails have an air space, or pulmonary sac, under the mantle that serves as a lung. The pond snails and some of the river snails breathe air, coming to the surface occasionally to take a fresh bubble into the pulmonary sac. The pond snails, like the whales, left the water and developed an air-breathing apparatus. Now they have gone to the water again.

How a snail walks and eats. A snail crawls on its single muscular foot, the fore part of the foot reaching out and then the back part drawing up toward it. Many snails secrete mucus in great abundance, and some smooth with a coat of this the pathway over which they crawl. They are active at night, and early in the morning their shiny trails may often be seen on rocks and boards. A snail's pace is said to be about 10 feet an hour.

A snail masticates its food by means of a toothed band stretched over its rounded, fixed, hard tongue. The band can be moved back and forth, and with it the snail shreds its food. In many species there are horny mouth pieces against which the toothed band works. Some snails pasture on hydroids. Others make the bivalve mollusks their prey. Have you seen a clam, scallop, or cockleshell with a small hole drilled in it? Such shells are common on the seashore. The holes are made by snails. A snail sits down beside the victim it has selected, or on it, and with its horny tongue begins to rasp a hole in the shell. This is a slow process, but the snail keeps filing away until the shell is pierced. Then it sucks the soft body of its helpless prey through the hole. One marine snail, the oyster drill, causes considerable losses in oyster beds.

Members of snail group. The whelks, tritons, winkles, and conchs are salt-water members of the snail tribe. The abalone (ăb'a-lō'ne), or ear shell, found on the California coast and used for food, also belongs to the snail group. Abalone shells are 9 inches across; they are beautifully lined with mother-of-pearl and are much used in inlaid work. The limpet is a relative of the snails that clings to rocks, often where it is exposed to the



American Museum of Natural Histor

A sea slug. The branched structures over the body are gills which serve to conceal the animal as it hides among the seaweeds on which it feeds. Some of the sea slugs are more than a foot long.

battering of the waves and to the air at low tide. Millions of limpets are used each year on the east coast of England as bait.

One branch of the snail family, the pteropods, has taken to life in the open sea. They are small and live in long, slender shells. The foot sticks out and has two flaps on it that are used as paddles. The pteropods feed on animals smaller than themselves and are in places present in immense numbers in the water. Some kinds of whales live chiefly on them, and large areas of the ocean floor are covered with pteropod ooze. There are many branches of the mollusk family, and this is one that struck out for a free ocean life.

The land and fresh-water snails are of many kinds. Some species are true amphibians, being able to live either in water or in moist locations on the land. Many land species are found over only a small area, each valley in some mountain areas having its own kinds. Land snails live hidden away, they eat vegetable foods, and in moist climates they are abundant. One species, the edible snail, is much used in France for food.

Slugs. Slugs are snails that lack shells or have only very tiny shells embedded in their backs. They are found on land and in salt water. They are common in gardens. A large kind introduced from Europe is troublesome in greenhouses because of its fondness for leaves. A sea slug on our Pacific coast, commonly called the "sea hare," may be 15 inches long. Many-of the marine slugs have fringe-like gills that stick out on their bodies and give them a resemblance to the seaweed on which they feed. At low tide they may be found on the seaweeds in shallow pools on the beach. Many of them, in striking contrast to their dull cousins of the land, are brightly colored — "frilly bits of exquisite blue, yellow, rose, orchid, or rust."

Success of snails. The snails have maintained themselves through a vast reach of geologic time. They have firmly established themselves in the sea, in fresh water, and on land. To what do they owe their success?

A part of the success of the snails must be credited to their adaptability. The group has developed many species with differences that adapt them to many environments and allow the use of a wide range of foods. A second factor in their success is the protective shell. The slugs have no shells and some of the forest snails have thin shells, but these live hidden away or are active only at night. The kinds of snails that lead an exposed life like the carnivorous ones of shore waters have thick shells which afford an even better protection than the lamellibranch shells against a foe.

The lamellibranchs, because of the way they obtain their food, are able to lead a completely sedentary (Latin sedens, sitting) life. In defense they are entirely passive, depending for protection on their shells. The snails eat and must move to their food, but in defense they follow the bivalve plan. They are satisfied to travel slowly and retain the advantage of a protective shell.

PROBLEM FOUR

What Are the Important Groups and Characteristics of the Cephalopods?

What do you suppose is the most powerful invertebrate animal in the world today? It is a cephalopod mollusk, the giant squid found off the banks of Newfoundland. Its body may be 8 or 9 feet long, its arms 40 feet long, and it may weigh 1000 pounds. It is a fierce, fighting, carnivorous animal quite capable of upsetting a small boat and both able and willing to take care of itself against all but the greatest monsters of the deep. The cephalopod plan of organization evidently allows for the development of animals of free activity and great size and power.

Early cephalopods. It was away back in the early Paleozoic when the first cephalopods appeared. They were little fellows, usually not over an inch long, and had shells shaped like a straight horn. As the animal grew it would occasionally creep forward in its shell and build a cross wall back of it. In this way it kept moving forward in its shell, and each house it occupied was larger than the one before. The animal lived in the mouth of its shell with its arms out, and seized other animals that came within its reach (page 840).

Soon the cephalopods began to increase in size, and in the Silurian seas we find some of them with shells 15 feet long. They were able to creep about on the sea bottom and some of them could swim. They were flesh eaters and had fierce beaks and long, strong arms. They were the first really powerful animals that the world knew and they ruled the seas of their time.

But the shells of the large cephalopods were heavy and awkward to drag about. The animal occupied only the front apartment anyway, and what to do with the long shells became a problem which the cephalopods solved in two ways. Some of them rolled their shells up. Others buried them in their backs and used them to stiffen the body. This gives two great divisions of the cephalopods, the coiled-shell type and the ones with no

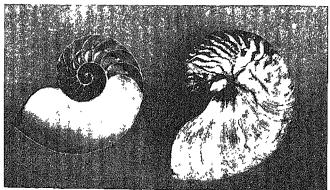
external shell. One group is represented today by the chambered nautilus and the other by the octopus and squid.

THE COILED-SHELL CEPHALOPODS

The fossils in the early Paleozoic rocks show that the first cephalopod shells were straight. In higher rock layers we find shells that are curved, then shells bent around in a loose coil, and finally shells that are tightly coiled.

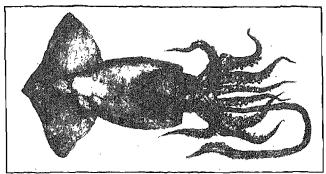
In Mesozoic times the coiled forms were very abundant. More than 6000 kinds have been described. Most of them were 3 or 4 inches across, but some of them were as much as 8 feet across and, if straightened out, the largest shells would have a length of 35 feet. They were very abundant in the Triassic seas, and in places their fossilized shells lie thick in the rocks. Often you see them in museums, and slabs of marble and limestone sawed out to show the coiled shells are sometimes used in mantels and floors. By the end of Mesozoic time, however, the large coiled cephalopods were gone and now only a very few small forms are alive.

Of the living coiled cephalopods the chambered nautilus is the best known. This is a rather small animal with a shell about 6 inches across. It lives in the waters about the Philippines and



American Museum of Natural History

Shells of the chambered nautilus. The one at the left has been sectioned to show the cross walls that the animal builds back of it as it grows.



American Aluseum of Natural History

A squid. These highly developed, active, free-swimming mollusks are very different from the bivalves and snails. The giant squid is by far the largest and most powerful of the invertebrates.

other islands in the Pacific and Indian oceans, spending its life creeping about on the bottom of the sea at a depth of several hundred feet. Like its ancestors of the old-time seas, it rests in the mouth of its shell with its head and arms out, and lives by seizing and devouring animals less powerful than itself. As it grows it extends its shell forward and from time to time cuts off a chamber back of it by building a cross wall in the shell. The compartments back of the animal are filled with gas, which in the water lightens the weight of the shell.

THE SOUID AND OCTOPUS GROUP

The other branch of the cephalopods is far from extinct. The giant squid is a rare animal, but there are in the sea smaller squids in abundance. Millions and millions of them are chasing through the sea the fishes and other animals of a size they can seize. In Mediterranean countries and in Japan they are caught in great quantities for human food, and they are the chief food of some kinds of whales. In the Cape Cod region 3,000,000 pounds of squid are used each year for bait.

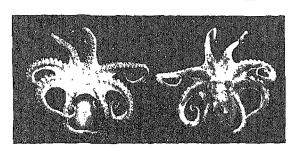
The squids. The squids are muscular and strong. Their long grasping arms are covered with cup-like vacuum suckers; they have cruel shearing beaks; their large eyes, like vertebrate

eyes, are fitted with corneas, lenses, and retinas. In the early stages of growth a shell begins to develop, but it soon becomes buried in the back. This buried shell, along with horny and gristly matter that is added to it, supports and stiffens the elongated body. The body of a squid cannot bend about as the body of a vertebrate does, but the long arms can shoot out in any direction and seize an animal that comes within range. The body is enclosed as in a cloak by a tough muscular mantle. In the mantle cavity on the lower side of the body are two gills.

The squids swim in a way that is all their own: they pump themselves through the water. When the mantle which encloses the body is relaxed, water is taken inside it. Then the mantle contracts and shoots a jet of water out of the mantle cavity through a tube that points forward. This drives the animal backward with astonishing suddenness. It darts through the water tail first with the arms trailing out behind. By pointing to right or left the tube through which the water escapes, the squid can change its course.

Squids (also the octopus) have a remarkable power of changing color to match their surroundings. They have also bags of ink which they can empty into the water jet and by using their ink they can in an instant shroud themselves in midnight blackness when an enemy appears. The shell in a squid's back is called the *pen*, because of the fanciful idea that the squid carries it to use in writing with its ink. The cuttlebone which is given to canary birds is the pen from the back of the cuttlefish, a close relative of the squids. An artist's paint (sepia) was formerly made from the squid's ink.

The octopus. The octopus is like a short, thick-bodied squid that in resting sits up on its arms. There are a number of kinds of octopuses, the largest weighing perhaps 100 pounds, with an arm spread of 15 feet. They walk about on the bottom of the sea or climb over rocks with their arms, and they swim as the squids do by pumping themselves along with the arms trailing out behind. They have strong cutting beaks and a paralyzing poison which they inject into a wound.



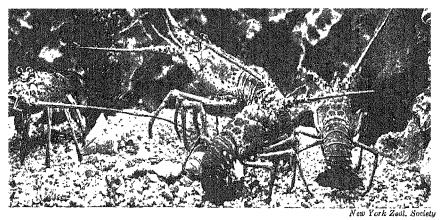
An octopus. The body is short and thick. The long tentacles are studded with sucking cups and the animal has a parrot-like shearing beak.

The octopus hides by squeezing its soft body into crevices and holes among rocks, and darts out on fish and crustaceans that pass by. When it seizes a crab it catches it from behind and holds the claws out away from the body so that the crab has no opportunity to use its pincers in defense. The octopus is abundant in shallow warm waters where the bottom is rocky, and in places does damage in crab and lobster fisheries. On our Pacific coast and in many other parts of the world it is trapped for human food. The octopus for its size is very strong. Only the vertebrates produce animals that match the giant squid and the octopus in power.

Ancestors of free-swimming cephalopods. The squids and their relatives are descendants of the belemnites (Greek belemnon, a dart), old-time cephalopods whose shells became buried in their backs. These free-swimming cephalopods appeared in early Mesozoic time, and were very abundant in Mesozoic seas. In some Cretaceous marl pits the pens from hundreds of belemnites are found. From the size of the pens it is believed that the belemnites must have had bodies up to 6 feet long. The giant squid is larger than any known ancient cephalopod, but most of the squids today are from a few inches up to about a foot in length.

The successful cephalopods — the members of the squid and octopus group — differ from the other mollusks in that they

have abandoned the idea of a defensive shell and have committed themselves to an active life. Their bodies are stiffened with an internal support and are strongly muscled, as the bodies of vertebrates are. They have weapons for offense and defense. They catch their food by pursuing it and capturing it with their long arms. They escape their enemies by their swiftness and their powers of concealing themselves. The lamellibranchs are sedentary, passive, defensive animals. The snails have moved to a degree toward an active life and some of them prey on helpless types of animals. The cephalopods have gone over entirely to an active mode of existence, and their bodies are in accord with the kind of life they lead.



Spiny lobsters. They are abundant in the warmer seas and lack the great claws characteristic of the Northern lobster.

PROBLEM FIVE

What Are the Characteristics and Adaptations of the Crustacea?

The word "crustacea" is from the Latin crusta, crust. The crustaceans are the animals with a crust. They are arthropods and wear their chitinous skeletons on the outside. In the larger forms the body covering is filled and coated with lime. You have seen this heavy, limy coat in the "shells" and claws of crayfishes and of crabs. The Crustacea are the great water branch of the arthropods. Most of us know them by the larger kinds like the lobsters and crabs, but water fleas and other little forms that are almost microscopic are more typical of the group.

THE LARGER SALT-WATER CRUSTACEA

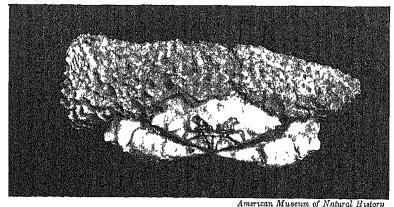
Among the marine crustacea of larger size are the lobsters, crabs, shrimps, and barnacles. Lobsters and crabs are bottom-living forms that inhabit shore waters. Shrimps likewise are abundant in shore water, but there are kinds of shrimps that swim at varying depths in the open sea. Certain species of rather large shrimps are called prawns. Barnacles have been mentioned in an

earlier unit (page 135) as crustaceans that have settled down to a sedentary life.

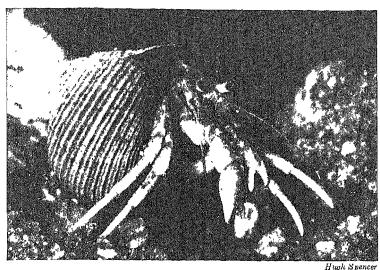
The lobster. The lobster is like a big crayfish living in the sea. Out of the water it appears to be an awkward animal, but at home it handles itself easily, shooting about in the water as the crayfish does. One weighing 27 pounds has been caught, which is the heaviest known weight for any living arthropod. Because the water supports the body, it is possible for a water arthropod to reach a size that it is not possible for a land arthropod to attain. On our Atlantic coast lobsters are most abundant toward the north — from Delaware to Labrador.

Lobsters are carnivorous, eating crabs or any other small animal on which they can lay their claws. Sometimes they fight fiercely with each other. They have an idea of land ownership, for one of them will claim a limited territory as his own and attack any other lobster that ventures into it. Lobsters for market are caught in traps called pots which are baited with fish. The mother lobster fastens the eggs to her swimmerets as the mother crayfish does (page 929).

The crabs. The crabs have small abdomens which are bent forward under the thorax so that they do not show when the animals are looked at from above. In shore waters crabs literally



The sponge crab plants a living sponge on its back. Other crabs carry sea anemones about.



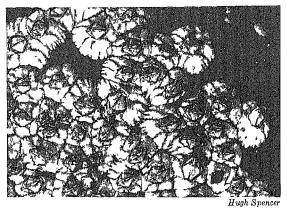
ti afly 12 heuce.

A hermit crab in the snail shell it has adopted for a house.

swarm, eating almost anything they can find. Many of the kind known as the blue crab are caught and sold as food on our Atlantic and Gulf coasts. When they moult they are "soft-shelled" crabs. One caught by another crab before the new shell has hardened is mercilessly destroyed.

There are a number of other kinds of crabs, the largest of which are the great spider crabs that are taken off the coast of Japan. These have a leg spread of 20 feet, but they are not as heavy as the biggest lobsters. The sand crab, which lives on beaches out of water much of the time, quickly buries itself if approached. The little fiddler crab has one large and one small claw. Sometimes these crabs almost cover the sand at the water line on a beach.

One of the most interesting of all is the hermit crab, which makes its home in the empty shell of a snail. One of these little fellows will go along, hunting for a shell of the right size. When one is found, the crab backs into it, but if the fit is not satisfactory it comes out again and continues the search. When a satisfactory home is at last selected, the crab backs into it and settles down with its claws sticking out of the opening. Often a sea anemone

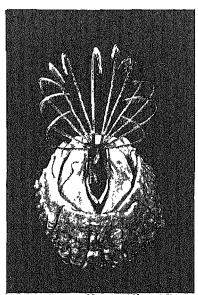


Barnacles are crustaceans that settle down and attach themselves to rocks, piles, ships, or other objects. They often cover every square inch of the rocks between high and low tide marks.

or a bunch of hydroids rest on top of the shell, which not only helps to hide the crab but gives it the advantage of their nematocysts for protection. As the crab grows it finds it necessary from time to time to move its home to a larger shell.

Barnacles. Piles and boats in salt water, sea cliffs, and

rocky ocean shores become covered with shelly animals. These are barnacles. They are crustacea that have developed the carapace until it encloses the body as a shell. They have feathery feet that extend out of the shell and wave in the water to bring in the small organisms the barnacles use for food. If disturbed, the animal draws the feet in and closes the shell. There are two types of barnacles — the acorn, or rock, barnacles and the gooseneck barnacles. Some of the snails have a grand time feeding over the thick-set barnacle beds. For a long time it was supposed that a barnacle was a kind of

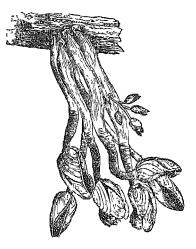


American Museum of Natural History

By kicking the feathery legs the barnacle sets up a current of water which brings to it the small organisms on which it subsists. mollusk, but when its development was studied it was found to be a crustacean that had given up a free life and settled down to live in a hydroid or crinoid way.

THE SMALLER WATER CRUSTACEA

From counts that have been made it is estimated that in the lakes of Wisconsin there are on an average more than 1000 small crustaceans in each cubic foot of water. In the sea they are by far the most abundant animals. Over vast areas they are thick in the water, being found at all

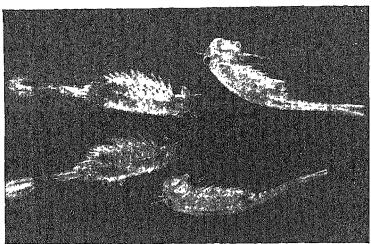


Goose barnacles. They are attached by stems and may be clustered as thickly as the rock barnacles. (After Goodrich.)

depths and even at the bottom in the mud and ooze. In open water the small crustacea hold much the same place that the insects hold on land.

Some of these small crustacea are practically transparent, which is a protection against their enemies. Many are microscopic. Those found in fresh water are commonly called water fleas, fairy shrimps, and other fanciful names. One kind common in ditches and sluggish streams is called cyclops because it has a single eye in the middle of its head. In books devoted to them you will find descriptions of many kinds.

These small crustacea are of the greatest importance as food for the larger water animals. The diatoms of the sea store the energy of the sunlight and manufacture vitamin D. Small crustaceans called copepods eat the diatoms. Larger animals eat the copepods and are in turn food for forms the codfish eats. Man then catches the cod, and we not only have its flesh for food but we find in its liver vitamin D, which in winter is used to keep man and his domestic animals in health. The herbage in the meadows of the seas and lakes consists of small plants,



Nature Magazine

Fairy shrimps are small transparent crustaceans that are abundant in fresh water. The plumy legs serve not only as oars but also as gills. They swim on their backs.

and more than any other animals the little crustacea are the harvesters who gather it and pass it on to us. If you want an interesting field for study you can find it in the tiny crustacea of any pond or lake.

THE LAND CRUSTACEA

A few crustaceans have made the transition from the water to the land. Some species of crayfish are almost land animals and in low-lying tropical coastal areas there are places where armies of vegetable-eating, burrowing crabs make their home on the land. Moreover, on some of the islands of the Pacific there is a large crab that is truly a land form. It passes the first part of its life in water, but at a certain stage of its growth it develops a rudimentary air-breathing organ under the carapace in addition to the gills. Then, as the toads and frogs do, it takes to the land. It is a vegetable eater and can shred the husk from a coconut and dig into the eyes to get at the meat. It even climbs the coconut trees and pinches off the nuts, which is a very remarkable thing for a crab to do. The land crab is of the hermit crab type and sometimes uses a part of a coconut shell for a house.

However, the commonest of the land crustaceans is a small one — the sow bug. Turn over a board or a stone that is on damp ground and you will probably find flat, little oval-shaped gray animals scurrying for shelter. These are not insects, but crustaceans quite similar in general structure to water kinds. They feed on vegetable matter and may cause damage by eating very young garden plants.

The Crustacea have the typical jointed external structure of the arthropod, which permits free movement. The skeleton is thickened and hardened in the larger kinds, which gives much the same advantage as a shell. They have produced an immense number of species, adapted to many different environments. The crustaceans are the most successful type of small water animals that follow an active life.

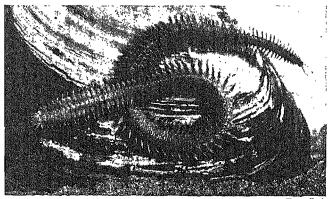
PROBLEM SIX

What Are Some of the Other Important Kinds of Water Animals?

Of the other kinds of water animals we shall mention only five. These are the marine worms, the Bryozoa, the rotifers, the small relatives of the vertebrates that have notochords but no backbones, and the vertebrates that are more primitive than the fishes. All of them except the rotifers are almost entirely ocean forms. The rotifers are mainly a fresh-water group with a few species living in the sea.

The marine worms. Two important kinds of sea worms are the segmented marine worms and the arrow worms. The segmented worms live near the shore. The arrow worms swim in the open sea. Some kinds of the segmented worms are commonly called sandworms (or clamworms) and flower worms.

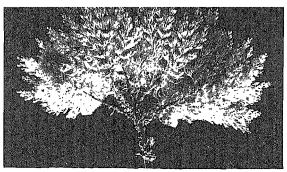
The segmented marine worms are annelids, relatives of the earthworms and leeches. In places along temperate shores they are very abundant. Many kinds burrow in sand or mud. Some species secrete stony tubes about their bodies, resting in these tubes with only the head out. The name flower worm is given



E. R. Bad

Sand or clam worms live in burrows in the sand near the low-tide mark. After dark they leave their burrows, to swim actively about and prey upon smaller animals.

to some of the group because of the brightly colored fringy gills and tentacles about the mouth. When the worms put the fore parts of their bodies out of the tubes and the gills float in the water, they look like flowers.



New York Aquarium

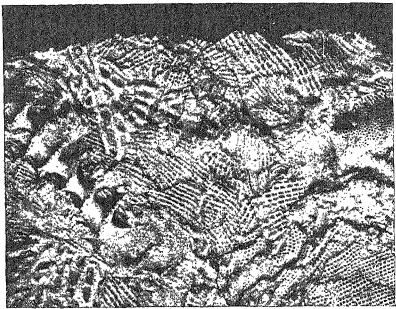
Bryozoa or "moss animals." They are found in both salt and fresh water. In places they form a thick carpet on rocks or on the sea bottom. They seem much like hydroids, but in their structure they are very different.

When danger comes the worms withdraw into their holes or tubes.

Some kinds of sandworms feed on mud and digest the organic matter that is in it. Practically the only animals of any size in the mud of the Zuider Zee in Holland are millions of "lugworms." These are members of the sandworm group. Others of the segmented worm group feed on seaweed; some are carnivorous, seizing small animals with their tentacles; others have on their tentacles cilia, which beat food particles into the mouth.

The arrow worms are not closely related to any of the other worms. They are small animals that are classed as worms only because of their general worm shape and lack of limbs and a skeleton. They live in the sea at all depths. Multitudes of them are often found swimming at the surface; they are found deep beneath the surface, swimming in the open water; and in the North Sea material dredged from the bottom practically always contains specimens of them. We think of worms as having their home in the earth, but they are abundantly represented in the sea.

The Bryozoa. The Bryozoa (Greek bryon, moss, + 200n, animal; moss animal) are like the hydroids in form but very different from them in structure. Most of them are marine, but a few live in fresh water. Typically, like Obelia and its relatives, they are colonial, an individual consisting of a branching group of



U. S. National Museum

Fossil Bryozoa from Paleozoic limestone. This animal group has flourished since early geologic time and rock layers are often in considerable part made up of their fossil remains.

many little zooids, which have ciliated tentacles and feed by the cilia beating food particles toward the mouth. The zooids have thin transparent shells or cups about them into which they can withdraw when danger threatens. The Bryozoans grow attached to seaweeds and other objects; many of them form encrustations on the surfaces of objects; the sea mats form a layer on the sea floor. Several thousand kinds of Bryozoa are known to be living today. They are found at all depths in the oceans from the tropics to the polar seas.

The Bryozoa are a very old group of small and curious animals. In the sea they grow in great numbers attached to marine plants, corals, and other objects. They form profusely branching colonies and seem most like the colonial hydroids; but in their internal structure and manner of feeding they are very different from these animals.

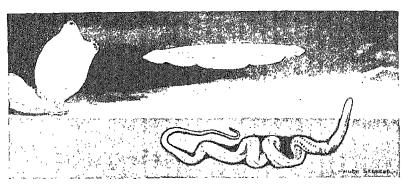
The brachiopods. The brachiopods are an ancient group of animals, some of which have lived practically unchanged from the time of the Silurian seas until today. They have a shell made of two parts, as is shown on page 989. At the back of the shell is an opening through which a stem extends out. Usually the animal is fastened to some object. The brachiopods look much like bivalve mollusks, but they are very different. The two sides of the shell correspond to the dorsal and ventral sides of the animal and not to the right and left sides.

Within the shell, a brachiopod has two peculiar coiled arms that are covered with cilia. It gets its food as the lamellibranchs do, by the cilia beating the water and creating currents that carry small food particles to the mouth. The brachiopods are entirely marine. In their body structure they are different from all other animals. They represent an old line that was formerly much more abundant than it is now. The brachio-

pods are sometimes called lamp shells because one side of the shell is shaped much like the small flat lamps in which the Romans burned oil.

Rotifers. Under your microscope, in water brought in from pools and ditches, you are likely to find curious transparent little animals somewhat larger than the largest protozoa. At the mouth end is a kind of disk and on this are two bands of cilia that move in such a way that there seem to be two wheels revolving about the animal's mouth. Sometimes the animals are attached by the forked tail end and sometimes they go whirling and tumbling about.

These little animals are rotifers, or "wheel animal-cules." They are not closely related to any other animals. They eat protozoa and small plants which are beaten down into the mouth by the cilia. The A rotifer. stomach has chitinous teeth inside, and the rhythmical movement of the teeth can be seen through the transparent body. If you find a tiny animal with teeth working in its stomach you may know that it is a rotifer.



Invertebrate chordates, the forerunners of the vertebrates. In the foreground is Balanoglossus; above is Amphioxus; at the left is a tunicate.

Rotifers are very resistant to drying. When a pool or a ditch in which they live dries up, they go into a dormant condition. They can blow about in dust without injury and resume their active lives when water comes again. They manage to reach practically all small bodies of water that might offer them a home, and the same kinds are found over wide areas.

Primitive chordates. There are a number of lowly relatives of the vertebrates in the sea. They have notochords but no jointed vertebral column. All of them have fine gill slits in the sides of the pharynx (throat), through which water taken into the mouth can be passed out.

The most primitive of the invertebrate chordates are the acorn worms (*Balanoglossus*). They burrow in the sand or mud of the seashore and get their food as the earthworm does. They eat their way as they burrow, and as the ingested (swallowed) material passes through the alimentary canal the organic matter in it is digested.

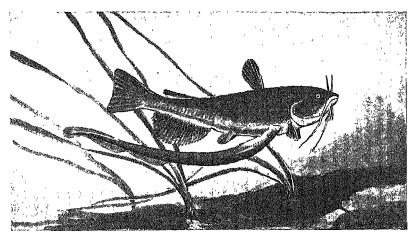
A second and much more numerous group of primitive chordates is made up of the tunicates, or sea squirts. In the early stages of their development they are tadpole-shaped and have a notochord. Soon the notochord degenerates, the body doubles up, and they develop into strange little animals. There are many kinds of them. Most of them grow attached, but some

are free-swimming. They live on microörganisms which they collect by straining water through the slits in the walls of the throat.

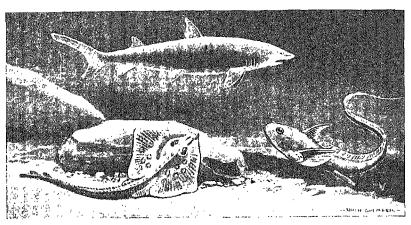
The one of the primitive chordates that is most like a vertebrate is Amphioxus, which has a fish-like form. It can swim, but it spends most of its time buried in the sand with its head out. It feeds by drawing water into its mouth and forcing it out through the gill slits, straining out in the process the minute organisms in the water. The amphioxus is 2 or 3 inches long and is found in shallow ocean waters over much of the earth.

Primitive vertebrates. The water-living vertebrates are the highest and most important of the water animals. They include the fishes, which have been discussed elsewhere, and two other groups that are more primitive than the true fishes. One of these groups is composed of the hagfishes and lampreys. The other includes the sharks, rays, and chimeras.

The hagfishes and lampreys (often called lamprey eels) are the most primitive of all vertebrates. They have smooth skins (no scales), no jaws, and no paired fins corresponding to the limbs of other vertebrates. The mouth is a round sucking organ with teeth set on the circular disk about it. The hagfishes live in the



A lamprey attacking a catfish. The lampreys are the most primitive of the vertebrates. They have no jaws and no limbs.



A shark, a ray, and a chimera. They have no gill covers and their skeletons are made of cartilage.

mud at the bottom of the sea and have no eyes. A few of the larger lampreys live in lakes, but most of them have their home in the sea and come up rivers to spawn. The little brook lamprey, which reaches a length of about 10 inches, spends its life in freshwater streams.

The blind but fierce hagfishes and the more powerful and larger lampreys live by making fish their prey. One of them attaches itself to the side of a fish and rasps a hole in its victim, sucking the blood and eating the flesh. The small and slender hagfishes often enter a fish and like a parasite within eat out the internal organs and flesh until only the skeleton and skin remain. The sea lampreys, which may be 3 or 4 feet long and as thick as a man's arm, accompany migrating fish (shad, alewife) upstream and work great destruction among them. Both the hagfishes and the larger lampreys are despised by fishermen because they destroy many fish caught in nets or on lines. The little brook lamprey feeds on dead vegetable and animal matter and does not attack living fish.

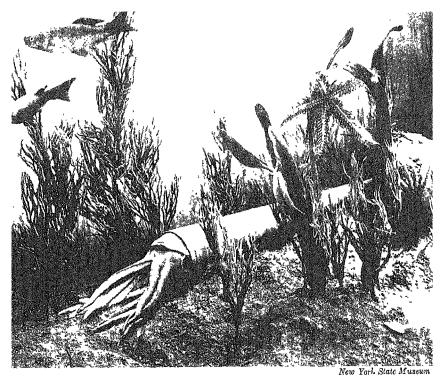
The sharks, rays, and chimeras have a skeleton made of cartilage. The rays are flattened creatures that lurk and feed on the bottom. The giant ray may be 18 feet across and weigh several thousand pounds. One kind of ray ("crampfish," "numb

fish") that can give an electric shock is found along our Atlantic coast. The sting ray ("stingaree") of Florida can inflict a painful wound with a poisonous barb on its tail.

The sharks are a varied and very old group. Some kinds are only 6 or 8 inches long and most of them are under 8 feet long. The largest measure up to 30, 40, or 50 feet. The dogfish of our Atlantic coast are small sharks and they are most destructive to lobsters, fish, and fishermen's nets. In the life of the sea the sharks since early Paleozoic time have held an important place.

Only three species of chimeras are known, and they are of no importance. The illustration shows the form of one of these. The largest species lives in the Mediterranean and has a length of about 3 feet.

Would you like to know of other types of water animals? If so, look up comb jellies or sea walnuts, nemertean worms, water spiders, and salps. Read about goose barnacles that attach themselves to whales, shipworms which are mollusks that bore into wood and stone, and the beautiful paper argonaut. Visit museums and note in ancient rocks the delicate markings called graptolites, which are the remains of an old group of colonial hydroids that are now extinct. There are many kinds of water animals of which the average person has never heard.



Animals of the Paleozoic sea. Radiative adaptation had produced this great diversity in water animals before land animals had appeared. The large animal in the center is a cephalopod.

DIVERSITY IN AQUATIC ANIMALS

The diversity among water animals is very great. Sponges, coelenterates, bryozoa, echinoderms, mollusks, and crustacea are constructed according to fundamentally different plans, and within each phylum the plan is endlessly and markedly varied. Doubtless one reason for this extreme diversification is that there are more ways of obtaining food open to a water animal than to an animal of the land. A second reason is the great age of the water forms. Water is the original home of life, and there has been more time to work out different types among water animals than among the comparative newcomers of the land. The most abundant living water animals are members of phyla that flourished in the Paleozoic era and have come down with undiminished vigor to our own time.

UNIT COMPREHENSION TEST

- A. Usually thirteen animal phyla are listed. How many of these are of importance on the land? Where do the others live?
- B. What body plan is typical of coelenterates? How does a hydroid differ from Hydra? Describe Obelia. What is a polyp? Make a diagram showing the life history of Obelia. Describe the structure of a jellyfish. How does it move and eat? Describe a sea anemone. What is the structure of coral? Where do the reef corals grow?
- C. What body plan is found in echinoderms? Describe the body of a starfish. On what does it feed? Describe the water-vascular system and tube feet. How does a starfish open an oyster or a clam? Describe an experiment performed with a starfish. Describe a brittle star; a sea urchin; a sea cucumber. How do sea cucumbers move? Describe the crinoids. How is the structure of crinoids adapted to their mode of feeding?
- D. Name the three divisions of the mollusks. What are the distinctive characteristics of the lamellibranchs? Describe the structure of a lamellibranch. How does a lamellibranch obtain oxygen? How is water passed through the gills? What do the lamellibranchs eat? Describe the body of a snail. How do the gills differ from the gills of a lamellibranch? How do the land snails obtain oxygen? How does a snail move? How fast is a snail's pace? How does a snail masticate its food? Mention some marine members of the snail group. What do land snails eat? What is a slug? How large are the largest slugs? Give reasons for the success of the snails.
- E. What is the most powerful living invertebrate animal? What were the early Paleozoic cephalopods like? In what two ways were the shells of later ones modified? What are the groups of living cephalopods? Describe the chambered nautilus. What is a squid like? How does a squid swim? How does a squid protect and defend itself? What is cuttlebone? Describe an octopus. How does an octopus capture its prey? In what kind of locations is it found? Describe a belemnite. When did the belemnites live?
- F. What are characteristics of the crustacea? Describe the lobsters; the crabs; the barnacles; the smaller water crustacea. Why are these small crustacea important? What are some of the land crustacea?
- G. Describe the marine worms; the bryozoa; the brachiopods; the rotifers; the primitive chordates. Describe the hagfishes and lampreys and tell of how they live. How do the sharks, rays, and chimeras differ from the fishes? Give possible reasons for the great diversity found among water animals.

SUGGESTED ACTIVITIES AND APPLICATIONS

- 1. Let the members of the class bring in specimens of as many kinds of water animals as they can find and classify them according to groups.
- 2. Take up a collection among class members and send to the Marine Biological Laboratory, Woods Hole, Massachusetts, for sea water and a group of marine animals. Materials for a 5-gallon aquarium cost \$5 and for a 10-gallon one \$10. In such an aquarium the feeding and moving of the sea anemone, starfish, hermit crab, and other marine forms can be watched.
- 3. Examine a clam (a fresh-water mussel will do). If you can secure a live one, place it in water and feed water colored with a little red ink into the intake siphon. See if the coloring matter appears at the other siphon.

Open a specimen and find the muscles that close the shell. Identify the mantle, gills, and foot. Clip off a small portion of a gill and examine it with the low power of the microscope. Note the sievelike structure of the gill. (An oyster may be used for the examination of the mantle and gills.)

- 4. Watch water snails in an aquarium feed and crawl. Why do aquarium owners like to have snails in their aquaria?
- 5. Let members of the class bring in any mollusk shells they have and try to identify them.
- 6. Dissect a squid. Identify the mantle, siphon (water tube), gills, beak, pen, and ink bag. Remove and open an eye and note the resemblance to a vertebrate eye.
- 7. Bring in water from lakes, ponds, or ditches and with the low power of the microscope examine it for small crustacea and rotifers. Watch for diatoms also as you examine the water (page 849). They are likely to be in the scum on the surface or at the edges of the water.
- 8. If you live near the seashore or visit it, collect and study other water animals mentioned in this unit.

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UNIT 19

LIFE IN THE SEA

The sea is not a waste, but a place of teeming life. The total amount of life in it probably exceeds the amount on the land.

"But what an endless worke have I in hand,
To count the seas abundant progeny,
Whose fruitful seede furre passeth those on land,
And also those which wonne in th' azure sky;
For much more eath to tell the starres on hy,
Albe they endlesse seem in estimation,
Than to recount the seas posterity;
So fertile be the floods in generation,
So huge their numbers, and so numberless their nation."
EDMUND SPENSER

Brown Brothers



AMOUNT AND VARIETY OF LIFE IN THE SEA

QUESTION FOR CLASS DISCUSSION

What kinds of marine plants and animals have you seen?

THE sea covers nearly three fourths of the earth's surface. Its bottom, lacking the mountains and valleys carved by the running waters of the land, is over most of its area so flat that it would appear level to the unaided eye. At places, however, there are volcanic upthrusts which may or may not rise above the water surface, and deeps where the earth's crust has gone down. Near most of the continental coast lines the sea bottom slopes gradually upward to form a "continental shelf" about the larger bodies of land. Into the sea the waters of the land constantly drain, bringing with them minerals that are required by plants and organic materials that animals can use for food. These additions from the land make living conditions more favorable in the waters of the sea, especially in the shore zone.

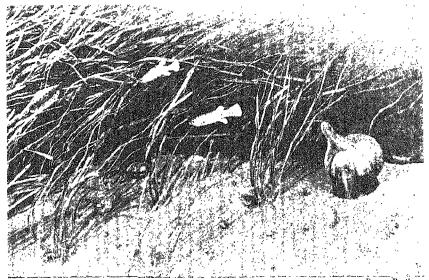
Life in the sea is adapted to different living conditions and to different ways of life. Some marine organisms are fitted for existence in the warmth of shallow tropical waters, and some are adapted to polar cold. Some are at home in the shore zone, some are free swimmers in open waters far from land, some live amidst the cold and stillness of the ocean floor. In their ways of obtaining food marine forms follow the same general methods adopted on the land. The sea has its green plants that build food and its herbivorous animals that subsist on the plants. There are in it, as on the land, hordes of large and small hungry carnivorous forms that prey on other animal life. There are ooze eaters that may be compared to the saprophytes of a forest floor. The larger organisms are afflicted with parasites as are the larger plants and animals of the land. No possible location or way of

living is neglected by marine life. The total amount of life in the sea probably exceeds the amount on land.

In one respect distribution of life in the sea differs entirely from its distribution on the land. On land, living things are confined to a surface layer. In the sea, organisms of various kinds are found through a vertical zone thousands of feet in extent. Over most of the open sea there is a wealth of vegetation in the upper lighted layer. This supports a great floating and swimming animal population whose members have their definite habitats at various depths. Still lower, as the bottom animal layer, are brachiopods, stalked crinoids, crabs with spidery legs that hold them above the mud, burrowing worms, and phosphorescent fishes of strange kinds. Away from the shores most of the green vegetation of the sea is made up of one-celled algae. Simple one-celled plants seem best suited to a floating water life.

Problems in Unit 19

- 1 What are the important plants of the sea?
- 2 What are some of the important animals of coastal waters?
- 3 What are the principal animals of the open sea?
- 4 What animals are found on the floor of the sea?



Brown Brothers

Eelgrass, a flowering plant that grows in shallow water along both shores of the Atlantic and furnishes food and shelter for small animal life. Recently much of the eelgrass was destroyed by a bacterial disease, but it is now coming back.

PROBLEM ONE

What Are the Important Plants of the Sea?

The important plants of the sea are eelgrass, seaweeds, and microscopic forms of which the most abundant are the diatoms. The eelgrass and seaweeds grow in coastal waters. The diatoms and other one-celled forms grow in multitudes in ocean waters down as far as light penetrates (1500 feet), being most abundant in the surface 500 feet. They are by far the most important part of the vegetation of the sea.

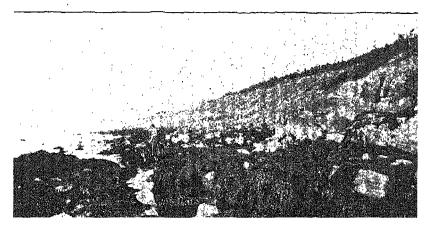
Eelgrass. Eelgrass is a monocot that has adapted itself to an underwater life in salt water. It grows rooted on muddy bottoms in shallow and comparatively quiet waters. It is found on both the eastern and the western shores of the Atlantic, but not in other oceans. Like grass on a prairie it covers large areas with a thick coating of vegetation that furnishes immense supplies of food and a hiding place for animals.

Some animals pasture directly on the grass. Others eat the mud and ooze of the eelgrass flats and live on the organic matter they digest from it. Much of this matter is carried farther out to sea by the waves and dropped in a zone below the deepest wave action. Here is the "mud line" where a multitude of ooze eaters dwell, the richest feeding ground of the sea. The eelgrass with the seaweeds furnishes much of the broken-up vegetable materials on which this animal population subsists.

Seaweeds. The seaweeds of the colder waters are mainly brown algae. Those of tropical waters include the red algae also. Some of these plants are quite large, but as in the mushrooms there is little tissue differentiation in them. They are masses of filaments made up of cells that are largely of one kind. The soft bodies of the plants float in the water and draw their food materials from it. The two most important groups of the browns are the kelps and the rockweeds.

The kelps grow along rocky coasts and often in stormy waters. Some of them grow where they are uncovered at low tide. Some grow in deeper waters, floating on the surface and being attached by holdfasts that chain them to rocks that are far below. Some of the kelps of our Pacific coast are several hundred feet in length. Large quantities of kelp are thrown up by storms on the New

Rockweeds and kelp on the coast of Nova Scotia. The photograph was taken at low tide.





U. S Bureau of Freheries

A branch of a red alga. A few species of these algae grow in fresh water, but most of them are beautiful feathery plants of the warmer oceans. England and Nova Scotia coasts and on those of northwestern Europe. It is gathered and spread on the land to add fertility. When torn from their moorings kelp plants are often carried to parts of the ocean which are unsuited to them and where they soon die.

The rockweeds grow clinging to rocks. They are branching forms, smaller and finer than the kelps. They have air bladders which cause

them to float and if they are torn loose they continue to grow, for a time at least, floating in the water. The sargassum weed is a rockweed, much of which is torn from the rocks of the Caribbean Sea and carried by currents to the great eddy in the Atlantic that is known as the Sargasso Sea. The supply of it here is constantly renewed; in the open sea it grows only slightly and does not multiply at all.

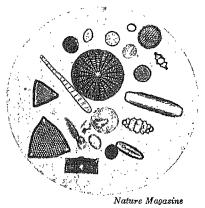
The red algae are found more in the warmer seas and in deeper water. They are more branched and feathery than the brown and far more beautiful. Masses of them growing on the rocks and coral formations look like bright gardens beneath the sea. Some of them (the corallines) become encrusted with limestone and look like fine coral growths.

Seaweeds as shelters. It is often said that where there is food animals will be present to eat it. This is not always the case. There are many open fields with food for birds and rabbits that have few of these animals; shelter from enemies is a condition of survival.

Seaweeds provide shelter for hosts of small sea animals. They provide also, in the moving and storm-tossed waters where they grow, anchorage that prevents the animals from being swept away. It is in areas of currents and waves that the food supply for animals is most abundant, and animals are far more numerous in the seaweed beds than in quiet eelgrass waters. Crustaceans, hydroids, and other small animals load down the branches of the plants. Each weed that drifts to the Sargasso Sea carries with it a host of snails, worms, prawns, small fishes, and other animals.

The diatoms. By far the most important of the marine algae are a family of little one-celled brown ones, the diatoms (dī'a-tŏms). More than 12,000 kinds of these have been named.

A diatom differs from all other plants in that it has a shell of silica, or quartz, like a little covering of thin glass. Diatoms multiply by longitudinal (lengthwise) division of the cell. Occasionally the protoplasm throws off its shell and conjugates with the protoplasm of another cell. In places that were once the bottoms of now vanished lakes and ponds, deposits of diatom shells are found. These "infusorial earths" are used as polishing powders and as filters. They are composed of millions and billions of the tiny glass-like shells.



Diatoms, which have shells of silica and grow by countless billions in the upper layers of ocean waters. They form the chief vegetation of the "pastures of the sea."

The diatoms are abundant in most fresh-water lakes and ponds, but their great importance is owing to the fact that they form the chief vegetation of the temperate and polar seas. In the upper layers of the sea, down to a depth of several hundred feet, immense numbers of diatoms grow. Tiny animals feed on these and larger animals feed on the tiny ones. Up and up the chain of life is built until it reaches the large fishes and whales. Nor

is this all. Down in the utter darkness of the ocean's floor, perhaps miles below its surface, a host of bottom-living animals feed on diatom ooze or stand with outstretched arms and tentacles to catch the diatom débris that falls down from above. On the animals thus fed other animals subsist. The diatoms are the foundation support of the teeming life of the sea.

Sometimes in the North Sea diatoms may number more than six million to a quart of water, and the water may feel smooth to the touch because of them. They flourish especially where the silica of which they build their shells is abundant. Near both the Arctic and Antarctic shores as well as in many other coastal waters there is a great diatom development.

Other microscopic plants. The diatoms are found more in the colder parts of the sea. In tropical waters life of all kinds is less abundant, but over much of the warmer seas vast numbers of microscopic swimming green algae (Peridinians) are found. Also, in some parts of the warmer oceans minute green algae (Coccolithophoridae) with calcareous (limestone) shells occur in such numbers that the waters appear milky because of them. There is also in many places a scum ("water bloom") on the surface of the sea that is made up of blue-green algae and other small plants, and in places along the shore green algae are found. Bacteria also are present everywhere in the sea.

The number of small plants in ocean waters varies greatly at different times and places. The great fishing grounds mark the regions where they most abound. Some of the minute sea plants are so very small that they pass through tow-nets made of the finest silk. Scientists who study them find their material in the stomachs of small animals that use the tiny plants for food.

On the land the larger kinds of plants prevail; a one-celled plant seems best adapted to a floating water life. The single green cell can take in its own supplies, give off its own wastes, make its own food. A zone of growth as deep as light penetrates is open to it. The one-celled plants constitute the chief vegetation of the wide and rich meadows of the sea.

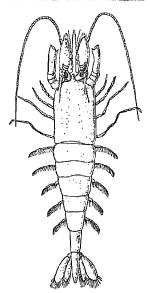
PROBLEM TWO

What Are Some of the Important Animals of Coastal Waters?

The coastal waters of the sea are an area of currents, waves, and tides. They are shallow enough to be well lighted and they are rich in minerals from the land. Eelgrass and seaweeds thrive in these waters and supply an abundance of vegetable food for animals. A great additional supply of vegetable material is washed down from the land. This strip of water along the junction of the sea and land is the most crowded of all areas in animal

life. Here competition between animals reaches its highest point; only the hardy, the adaptable, or the well-concealed survive.

Shore and mud-line zones. The coastal waters of tropical and temperate regions may be divided into a shore zone in which the eelgrass and seaweeds grow, and the mud line which is really a wide zone where in deeper water materials are deposited on the ocean floor. The life of the shore zone varies greatly from the tropics to the colder regions and also locally according to whether the shore is rocky, muddy, or sandy. Some places there are wide sandy beaches almost barren of life, and in other places up to the very margin of the land there is crowded life. The combined length of the coast lines of all the oceans, gulfs, bays, and other inlets

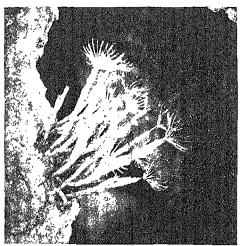


A shrimp. Shrimps of many kinds are abundant both along coasts and in the open sea. The larger kinds are much used as human food.

of the sea is 150,000 miles. The coastal waters cover an area of 9,000,000 square miles—nearly three times the area of the United States.

The shore zone. Over great areas in shore waters there is a dense growth of eelgrass or of seaweeds, but surprisingly few animals pasture directly on the plants as do many insects and the large herbivorous animals of the land. Most of the animals subsist on broken-down vegetable matter. For the most part the plants die and break up into fine particles (detritus) in the water. Then the sponges, numerous mollusks like the oyster and clam, worms, and other animals feed on this vegetable matter by straining the particles from the water or by swallowing the mud.

Among these herbivorous forms range a host of carnivorous ones — starfishes, crabs, snails with file-like tongues that rasp holes through the shells of other mollusks and suck out the body of the animal within. Fishes are everywhere; some of them (mullet) browse on seaweeds, some eat detritus, many of them feed on other fishes and on the lower and slower forms of animal life. Squids chase the smaller fishes near the surface; the cuttle-fish conceals itself in the sand; and the octopus hides in crevices of rocks as it lurks for its prey. Shore birds feed on the animals of the beaches and shallow waters, and seals and dolphins are

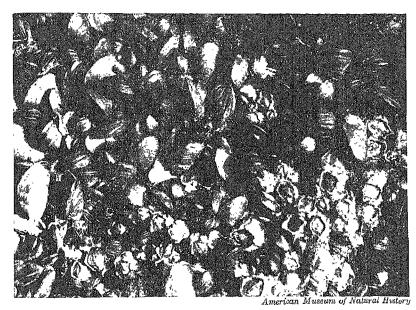


American Museum of Natural History

The flower worms build tube-like shells of calcium carbonate. When the heads with the feathery gills are extended, the animals have the appearance of flowers.

often in the shore zone. The sea not only feeds its own inhabitants, but supports some of those whose real home is the land.

Shore zone in different latitudes. In the shore zone of the temperate regions the seaweeds are covered with snails; bivalve mollusks abound; crabs, shrimps, prawns, and other crustacea are found in immense numbers. There are sea anemones, hydroids, and barnacles



Crowded life of the shore zone. The photograph shows sea mussels and barnacles attached to a rock.

clinging to the rocks and other supports, waiting to eat any small animals luckless enough to come within their grasp. There are starfishes preying on the oysters and clams, and sea urchins feeding on vegetable materials. There are worms in multitudes living in tubes or burrowing in the sand or mud, sponges, carnivorous snails, fishes, tunicates and other primitive relatives of the vertebrates, and multitudes of smaller animal forms.

In tropical and subtropical regions corals and sponges are more numerous. Seaweeds attached to the great coral reefs are loaded with crustacea, hydroids, snails, and worms. At times immense numbers of jellyfishes are in the water; fishes great and small abound. On sandy shores rays lie partially covered with sand or move slowly along, crunching mollusks or crustaceans or seizing fishes that come within their reach.

In Arctic and Antarctic regions the food is provided not by vegetable matter from the shore or by larger plants, but by myriads of diatoms which grow in the upper waters. These areas are especially favorable for animals that can collect the small plants by straining them from the water. The sea mussel grows in especial abundance in Arctic waters and constitutes practically the whole food of the walrus. In Antarctic waters penguins subsist on crustaceans and fish.

The mud line. In quiet waters in any part of the world the mud line may be near the shore, but where the storms sweep the coast it is a distance back from the shore. The highest waves stir the water to a depth of about 600 feet. As they break on the beach and draw back, they carry with them materials which they deposit in the quiet waters of somewhat greater depth. At 600 feet in even the clearest water the light at brightest noon is of the intensity of pale moonlight and there is little plant growth, but from this depth down to 1200 feet a great abundance of animal life is found. Here, where wave motion dies away and abundant food is brought outward from the shore, are



Menhaden piled on a North Carolina beach. A large school of these fish tried to pass through a shallow strait. The oxygen dissolved in the water was exhausted and the fish died of suffocation. The illustration gives an idea of the abundance of life in the sea.



Fish and Wildlife Service, U. S. Bureau of Fisherics

Seals are among the mammals that feed on the bounty of the sea. It is estimated that it requires 3,000,000 pounds of fish each day to support the seal herd that comes down in the spring on the ice floes off Labrador.



Ewing Galloway

Gulls in Icelandic waters photographed from a Norwegian fishing vessel. Millions and millions of birds live from the abundance of the sea.

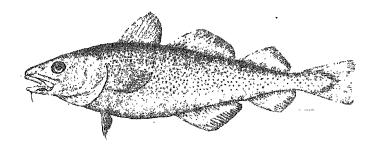
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multitudes of crabs, starfishes, sea urchins, crinoids, mollusks, and worms. Fish are abundant; along nearly all coasts there is fishing in the mud-line zone. Weakfish, the fluke or summer flounder, bluefish, striped bass, croaker, halibut, bass, and salmon are some of the kinds of fish caught in our East and West coast waters. Barracuda, yellowtail, amberjack, tarpon, Spanish mackerel, red snapper, and many other species are found in the subtropical waters of the Gulf and the Florida coasts.

The great fishing grounds. The great fishing areas of the earth are four in number. One is the North Sea, one is the Grand Banks of Newfoundland, one is the Bay of Biscay west of France, and one is in the waters near Japan. These fishing grounds are regions where there is a great concentration of microscopic life. They are also areas of comparatively shallow water where materials from the small organisms that die collect on the ocean floor at moderate depths. The fishing grounds are not coastal waters, but they are of mud-line depth and they are adjacent to land areas, where rivers bring the influence of the land to bear on them. They are comparable to the mud-line zone except that the material on the bottom comes from microscopic organisms instead of being swept outward from the shore zone.

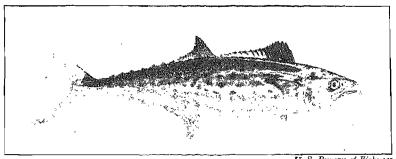
In the fishing grounds the waters are filled with small crustaceans that collect the microscopic plants and feed on them. In places multitudes of pteropods occur (see page 860). On the Dogger Banks in the North Sea there is an area 20 miles wide and 50 miles long where on an average the small bivalve mollusks on the bottom number from a thousand to seven thousand on each square meter. The waters of the fishing grounds teem with small life and this supports the fishes that are important for human food.

Some fishes like the herrings, mackerel, and shad swim through the water with open mouths and strain their food from the water. They have bony comb-like structures on their gill arches (gill rakers) which catch the small organisms on which the fish feed and allow the water to pass out over the gills. The flatfishes



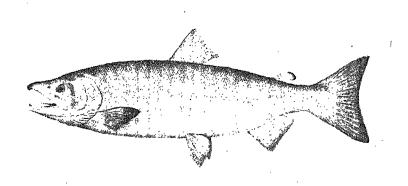
Codfish

U. S. Bureau of Fisherics



Spanish mackerel

U. S. Bureau of Fisheries



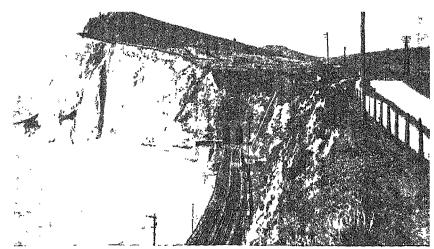
Red salmon

U. S Bureau of Fisheries

Three important food fishes. Many of the salmon go up rivers to spawn and are taken on their migratory journeys.

(flounders, turbot, halibut, sole) are a group of bottom-living kinds that move about, feeding on bivalves, snails, worms, and other animals of the sea floor. The cod is a heavy-built free swimmer that goes about in hungry shoals, feeding on other fishes and also on the crustaceans, mollusks, and other bottom-living animals. The haddock prefers echinoderms and crustaceans; the sole, worms; the whiting, smaller fishes. Many of the bottom-feeding fishes have powerful teeth with which they crush the shells of the mollusks and crustaceans they eat. Forty whelks (a large carnivorous snail) were found in the stomach of a single rock cod.

The amounts of human food furnished by the coastal waters and fishing grounds of the sea is very great. One boat in the North Sea may catch 100,000 herrings in a day. The total number caught by boats from the port of Yarmouth alone may be 30 million in a single day. A school of mackerel a half mile wide and 20 miles long has been seen. Another was estimated to contain a million barrels of fish, and in a good year 50 million barrels of mackerel are caught. Not only fishes but also oysters, clams, crabs, shrimps, and other marine animals contribute to our food supply. In many locations man lives more easily from the coastal and shallower parts of the sea than from the land.



Dwng Galloway

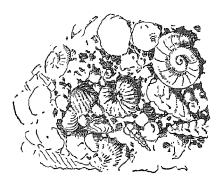
The famous chalk cliffs of Dover, England, were formed by the accumulation of microscopic Globigerina shells. They afford an inexhaustible supply of material for the manufacture of cement.

PROBLEM THREE

What Are the Principal Animals of the Open Sea?

The floating and swimming animal population of the open sea is made up of herbivorous forms that subsist on diatoms and other microscopic plants, and of carnivorous species that live on the herbivorous ones. Since in the open sea all the vegetation is microscopic it is evident that many of the animals must be able to feed by collecting small forms. The organisms that float and swim in the sea far from land are spoken of as *pelagic* (Greek *pelagos*, sea) forms. In size the pelagic animals range from protozoa to whales.

Marine protozoa. Living among the microscopic plants in the surface waters of the sea are myriads of protozoa. Many of them have shells with minute openings through which extend long strands or arms of living protoplasm. These protozoa feed by gathering in diatoms or other small plants with their long arms and digesting them in the protoplasm with which they engulf them. The most abundant of the protozoa that have shells are



Shells in a piece of chalk, as seen under a microscope.

the Globigerina and Radiolaria. The former have a calcareous shell and the latter a glass-like siliceous shell. The collection of their disintegrated shells on the ocean floor forms Globigerina and Radiolarian ooze. From Globigerina shells chalk is formed.

Another protozoan that is abundant in warmer

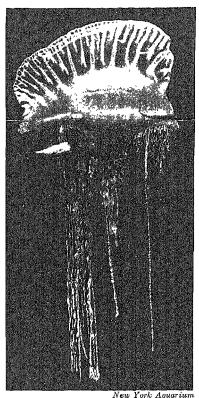
waters is Noctiluca, a free-swimming form with no shell. It is phosphorescent and is often so abundant that for miles the breaking waves are made luminous by it. In the waters of Chesapeake Bay, Noctiluca may cause the water at night to be fringed with light as it slips from the oar.

Pteropods and copepods. At places in the sea are multitudes of little free-swimming snails that are called pteropods. These little mollusks have the foot expanded into two flaps with which they paddle themselves through the water. They feed on minute organisms that they collect from the water and in some regions they are so abundant that the ooze which collects on the sea floor is called pteropod ooze.

Even more abundant are little crustaceans called copepods. In places for many miles the surface layer of the ocean water may be thick with them; in the North Sea the average copepod population is estimated to be 1700 to each square foot of water. The pteropods and copepods, especially the copepods, are the chief food of the whalebone whale. The whale opens its mouth and rushes forward, straining the water through its whalebone plates as it goes. Barrels and barrels of copepods that are collected in this way may be found in a whale's stomach. The basking shark is another great creature that collects its food by straining out small pelagic forms. The copepods feed on diatoms and are themselves food for higher forms.

Other free-swimming invertebrates. Arrow worms live in multitudes in the open They are active, predaceous little creatures that seize their food with pincer-like jaws. Shrimps are in great numbers. and multitudes of smaller crustacea are found. Some annelid worms swim actively about, and in many regions squids are so abundant that they form the chief food of the toothed whales. Jellyfish are surprisingly abundant. The largest ones are 7 feet in diameter and have tentacles that trail in the water to a distance of 120 feet.

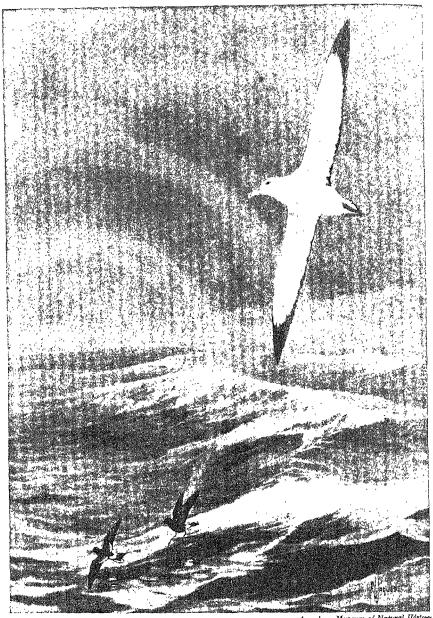
One of the free-swimming forms that often attracts attention is the Portuguese man-ofwar. It is a hydroid colony with a hollow gas-filled float and long trailing arms, each of which is a polyp. Some of the polyps do the eating for the



The Portuguese man-of-war, a floating hydroid colony. The long tentacles are armed with nematocysts and may have a length of 50 feet or more.

colony; some are covered with nematocysts and serve as stinging and food-capturing arms; some bud and reproduce the organism. The float of a Portuguese man-of-war may be up to 12 inches long, and the stinging tentacles of a large specimen may be 50 feet long.

Pelagic fishes. Sharks and many fishes great and small spend their lives swimming about in ocean waters. Some of these fishes are solitary or go in small groups. Some, like the mackerel and flying fish, go in schools. As we have stated, the mackerel gain their food by straining it from the water, but most of the



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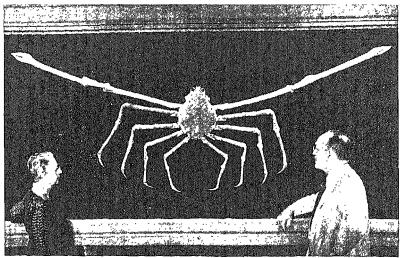
All the birds nest on land, but the great southern albatross may be regarded almost as an animal of the open sea. It soars tirelessly hour after hour and ventures thousands of miles from land. It rests and feeds by dropping into the ocean and riding the waves. The smaller birds in the illustration are petrels, which are also found far out at sea.

larger fishes live by catching and devouring animals of some size. The swordfish, sailfish, and tuna are pelagic fishes that are often captured for sport.

Life in tropical and polar waters. One of the most surprising facts in connection with the sea is that life is much more abundant in polar than in tropical waters. The reasons for this are not yet well understood. One suggested reason is that bacteria grow more rapidly in the warmer waters and more quickly break down the nitrogen compounds which are necessary for the growth of green plants. Another possible explanation is that in the colder waters the animals live and grow more slowly and use less food, and therefore they live longer and there is more overlapping of the generations in the colder waters.

Whatever the reason or reasons may be, the fact remains that in both the Arctic and Antarctic oceans the waters teem with life, while in the great oceans of the tropics life is comparatively rare. Agassiz stated that in the upper waters of the Pacific from Japan to Chile little life is found. He called the whole central and southern Pacific a "barren region." Perhaps this barrenness is associated with the lack of land and of the mineral and vegetable materials that come from the land.

The only warm-blooded animals that are truly pelagic are the whales. Some kinds of seals pass most of their lives making long migratory sea journeys between their summer and winter homes, but they and all other marine mammals except the whales rear their young on ice floes or on land. Penguins and other oceanic birds spend long periods at sea, but they likewise return to the land for breeding purposes. Only the whales among the warm-blooded vertebrates are entirely independent of the land.



Science Service from Buffalo Museum of Science

A Japanese spider crab with a leg span of 11 feet. The long spidery legs hold the animal above the mud of the sea floor.

PROBLEM FOUR

What Animals Are Found on the Floor of the Sea?

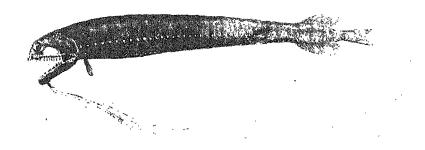
Around each of the large land areas is a continental shelf over which the water is of only moderate depth. Then the sea bottom slopes sharply downward to a much greater depth, forming the basin of the deep sea. Few bottom-living species of animals make the journey up or down the sharp continental slope. The forms that live on the bottom in shallow water are different from the animals of the sea floor. The bottom-living animals of the deep sea are referred to as abyssal animals. They are the animals that live in the abyss of the sea.

Conditions in the deep sea. The average depth of the sea is about 2½ miles and its greatest known depth is more than 6 miles. The temperature of the deep water, in both the tropic and frigid areas, is almost down to the freezing point. On the sea bottom there are no projecting rocks; the bottom is level and

covered with a soft ooze. In the great depths darkness is total; there is no plant life and no food except that which falls from above. The only movement of the water is a mass flow toward the equator, so slow that it would be imperceptible. Conditions in the deep sea are the most nearly constant of any found on earth.

Characteristics of abyssal animals. The bottom-living deep-sea animals are adapted to the conditions under which they live. They are not required to battle waves and currents and in general they are light in build — not heavily muscled or equipped with heavy skeletons. The fishes usually are not more than a foot in length and are noted for their fierce teeth and swallowing powers. There are many adaptations among the animals to the soft floor. Some burrow in the ooze. Many have long stalks that lift them above the mud. The crabs have long spidery legs. Most of the animals are dark or reddish in color — blues and greens are never found. Phosphorescence is common. Corals have been brought up from the depths that at a distance of 6 yards gave sufficient light for reading.

Kinds of animals on deep-sea floor. In the depths of the sea there are sea cucumbers burrowing in the ooze and feed-



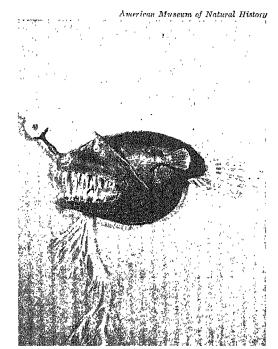
American Museum of Natural History

A fish taken at a depth of over 3000 feet near the island of Sumatra. The rows of luminous spots along the sides, arranged like the portholes of a liner, are common organs in deep-sea fishes. The cold phosphorescent light they shed may be yellowish, bluish, or even intense purple. Many, perhaps a majority, of deep-sea animals are phosphorescent.

ing on it. There are crinoids with long stalks that have root-like branches at their lower ends. Sea pens and other corals that stand upright are common, as are hydroids, tunicates, and sponges. Brachiopods, practically unchanged since Paleozoic time, lie on the ooze. Crabs walk about on their long stilted legs and sea spiders, which are small-bodied, long-limbed little animals closely related to the crustacea, are inhabitants of the sea floor. Fishes, of course, are a prominent feature of abyssal life. They are present in surprising numbers and of the most astonishing kinds.

Probably the animals of this cold and timeless region live slowly and are long-lived. It is possible that life accumulates, as it were, and that there is less of it in a century or a millennium than the amount we find at any one time would indicate.

Food of deep-sea animals. The basic food of bottomliving deep-sea animals is the diatom and other débris that drifts down to them from above. In this are included the bodies of pelagic animals which disintegrate and reach the sea floor in



minutely divided form. The crinoids catch this material on their outstretched arms and work it along the grooves in their arms to their mouths. The tunicates filter it from the water. The hydroids, corals, brachiopods, and sponges secure their shares of it by their food-

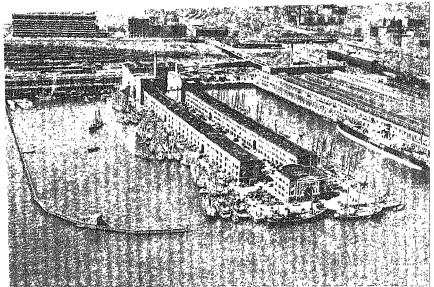
The deep-sea angler has luminous appendages which float out and lure other fish within reach of the waiting jaws. Many deep-sea fish have stomachs and body walls so elastic that they can swallow other fishes larger than themselves.

collecting plans. Sea cucumbers and worms eat the sediment of the sea floor and digest the organic matter that it contains.

Then there lives among these detritus-subsisting organisms, and preys upon them, a group of larger carnivorous animals, chiefly crabs and fishes. Bivalve mollusks and snails are rare.

Sea-bottom fishes. The bottom-living fishes are an astonishing lot. Many of them have rows of phosphorescent lights. Their eyes are large, their mouths are formidable, their dispositions fierce, and their swallowing powers beyond belief. When they have an opportunity for a meal they make the most of it, and some of them have stomachs and body walls that will stretch until they can swallow other fishes three times as large as themselves. Among all the animals of the earth these bottom-living fishes stand out as a most fantastic group. One was brought up from a depth of more than 19,000 feet.

No one has seen the bottom of the deep sea. What we know of it has been learned by letting down tow-nets and examining the contents of the nets. Our knowledge of the sea floor and its inhabitants may be compared with what we might learn of the land surface by letting down nets from high balloons and dredging up samples of the living things of the land. Obviously we should not catch many foxes, rabbits, or birds in this way and it may well be that there are many forms of deep-sea life that man has not seen.



Fairchild Aerial Surveys, Inc., courtesy Massachusetts Fisheries Association

The fish pier at Boston and a few of the ships that go out from it to gather the bounty of the sea.

THE RICHES OF THE SEA

One purpose of this unit is to give a slight understanding of the economic possibilities of ocean life, for the poetic phrase, "old Ocean's gray and melancholy waste," is a misleading one. The sea is not a waste but a place of teeming life. It is merely a region as yet largely unexplored by man and with its riches only to a slight extent put to human use. In the food-gathering (hunting and fishing) days of Europe only a scattered and sparse population was supported by the land. The populous settlements were on the margins of the sea, where the more abundant food resources were close at hand.

To a considerable extent man has conquered the land, cultivating the plants and caring for the animals that are useful to him and exterminating or holding in subjection the undesirable forms. The sea is yet wild and from it the fishermen, like hunters in a new country, bring back only that which nature has prepared for them. Someday we shall farm the sea and appropriate for our use much more than we do now of its great wealth.

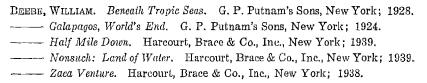
UNIT COMPREHENSION TEST

- A. Why is the bottom of the sea more level than the land? Compare the life of the sea with life on the land. How does the distribution of life differ in the sea and on land?
- B. What are some of the important plants of the sea? Which of these is the most important? What is eelgrass? Where does it grow? To what plant groups do seaweeds belong? Describe the kelps and rockweeds. What are the characteristics of the red algae? Where do they grow? In what ways do seaweeds serve the small animals of the ocean? To what plant group do the diatoms belong? How do diatoms reproduce? What are deposits of diatom shells called? Where are diatoms most abundant? Why are they so important? How abundant may they be in the North Sea? What microscopic plants are found in tropical seas? What is the prevailing type of plant life in the open sea?
- C. Why is life so abundant in coastal waters? Distinguish between the shore and the mud-line zones. Describe the life of the shore zone. How do the animals of the shore zone in warmer regions differ from those of temperate regions? What plants provide the food in polar areas? How deep is the water in the mud-line zone? What is the source of food in this zone? What are important animals found in the mud-line area? What are some of the important fish of coastal waters? Where are the great fishing grounds of the earth located? How do they differ from other regions of the ocean? What are some of the important fish taken in the fishing grounds? Why is the life in the sea important to us?
- D. What does the word "pelagic" mean? Describe several types of marine protozoa. Describe pteropods and copepods and tell about their occurrence. What animals feed on them and how do these animals collect them? Name some other free-swimming invertebrate animals of the sea. What are some of the important fishes of the open sea? On what do they feed? What reasons have been advanced to explain the fact that life is more abundant in polar seas than in tropical waters? Tell about the mammals and birds that live from the sea.
- E. What does the term "abyssal" mean? What is the average depth of the sea? What is its greatest known depth? What is the temperature of the deep water both in tropic and polar seas? What are some of the general characteristics of animals living on the bottom of the deep sea? Name some of the kinds of animals found on the deep-sea floor. What do these animals eat? Describe some of the abyssal fishes.

SUGGESTED ACTIVITIES AND APPLICATIONS

- 1. Make a list of foods from the sea that are sold in the meat markets and stores of your town or city. Include canned foods.
- 2. Read any or all of the books listed below and write an imaginary account of a trip under the sea.

References





UNIT 20

THE LAND PLANTS

The land plants through a long course of development from group to group have adapted themselves to practically all conditions of the land. Man and all other land animals are dependent on them for support.

"Let us tell the story of the Land-plant as it ought to be told, beginning, as is right and proper, with a humble beginning, tracing our hero's many vicissitudes, and following the tule to its happy ending. . . . It is a story worth following, since to grasp it gives a new meaning to every tree and flower."

H. G. WELLS

GROUPS AND ADAPTATIONS OF THE LAND PLANTS

QUESTION FOR CLASS DISCUSSION

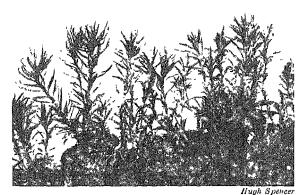
Which is the more successful type of organism, the land plant or the land animal?

THE four plant phyla are the Thallophyta, Bryophyta, Pteridophyta, and Spermatophyta. The last three of these phyla are our subject for study in this unit.

The purpose of the unit is to develop an acquaintance with the great groups of land plants and to note their relationships and the adaptations that they show for a land life. Our study will lead us into the field of ecology, a branch of biology which deals with the relations of organisms to their environment. The term "ecology" is derived from the Greek word oikos, house. Literally, the ecology of a plant or an animal means its housekeeping arrangements — the way it carries on the affairs of its daily life. In discussions of plant ecology the term plant society is frequently employed. A plant society is a group of plants of different species, growing together and forming a plant community.

Problems in Unit 20

- 1 What structures and adaptations do the bryophytes show?
- 2 What are the characteristics of the pteridophytes?
- 3 What are the characteristics and groups of the gymnosperms?
- 4 What are the characteristics and groups of the angiosperms?
- 5 What are some of the more important ecological relationships of the land plants?



Leafy shoots of moss.

PROBLEM ONE

What Structures and Adaptations Do the Bryophytes Show?

The mosses are too small to compete for the more fertile places of the earth. Among the trees and the plants of the fields and roadsides they are as pygmies in a world of giants. In consequence, we find them on the Arctic tundras, in bogs, on the banks of streams, clinging to trees and rocks, and on sour and barren lands. They grow, not in the choice places, but where they can.

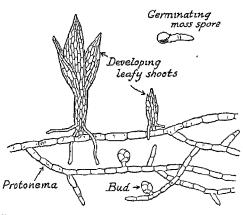
The moss plant. In moist, shady places in the woods we may find moss growing upright in beautiful green clumps. When we examine it we find that a clump is made up of many little erect shoots. Each has a stem and leaves. Down at the base are small thread-like structures. These are the *rhizoids* (rī'zoids; Greek *rhiza*, root, + *oeides*, like; root-like), which serve as roots. Like one of the larger plants, the moss shoot gathers water and minerals from the soil and has leaves to make its food.

Sometimes on top of the moss plant we find little stalks standing up like bristles or stiff hairs. On the end of the stalks there may be tiny pods or capsules. What are these? If you crush the capsules and examine the contents under a microscope you will find that they are filled with the small round spores that reproduce the plant. Let us begin with one of these spores and follow through the life history of a moss plant.

Development of moss spore. If a moss spore falls on damp earth or some other place favorable for its growth, it germinates. The wall bursts open and a little green tube comes pushing out. Growth continues and cell walls come in. Soon there is a branching filament like a green alga. This is called the *protonema* (prō'to-nē'ma; Greek *protos*, first, + nema, thread or filament). It does not look in the least like a moss plant.

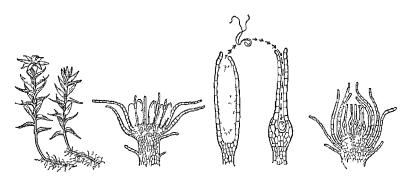
After a time, as the protonema grows along on the earth, little bud-like structures, *bulbils*, appear on the ends of its branches. These develop into slender, green stalks that grow upward. Then swellings push out on the sides of the stalks; the swellings grow into leaves; and the leafy shoot has taken form. The protonema branches freely and produces many bulbils, which grow into the numerous leafy shoots that stand close together in a moss clump.

Sexual reproduction. Now comes a distinct event in the life of the moss plant. On the tops of some of the shoots compact



The moss spore grows into the filamentous alga-like protonema. The leafy shoots arise from buds ("bulbils") that develop on the branches of the protonema.

little rosettes of leaves appear, and in among these leaves microscopic pod-shaped organs grow These are called antheridia (singular antheridium). They are organs for developing male gametes. sperms. In each of them sperms are produced in enormous numbers and are discharged in multitudes when they Each are mature.



Antheridial and archegonial shoots of moss (left) with sections through the tops of each. In the center is a single antheridium and an archegonium with a diagrammatic representation of the passage of the sperm to the egg.

sperm has two cilia like the Ulothrix or Oedogonium swimming gametes (page 232).

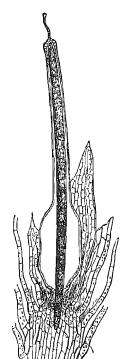
On other shoots, or in some kinds of moss on the same shoots, other little flask-shaped organs develop. These are the *archegonia* (ar'ke-gō'nĭ-a; singular, *archegonium*). In each of these an egg is produced. When the egg is ready for fertilization the neck of the archegonium opens so that the sperms can enter. The sperms have only the moisture of the dews or rains in which to make their way, but enough of them reach their destination to fertilize many of the eggs. Then the eggs are ready for further growth.

Development of fertilized egg. A moss egg stays right where it is to begin its growth. Up on top of the leafy shoot, resting in the old archegonium, the egg divides into two cells and then into four. On and on the growth goes until a mass of tissue is built up that develops upward into a stalk and sends a foot downward into the tissues of the leafy shoot below. This is the stalk you have seen on top of the leafy moss plant. It is a parasite on the mother plant, but it continues its development until it produces a capsule and forms spores. Then the spores are shed, they grow into protonemas, and the cycle is gone through again.

The moss a double plant. The moss, as we have studied it, is not one plant, but two. The protonema and leafy shoot,

taken together, make up one plant. Botanists call it the gametophyte (ga-mē'to-fīt), which means simply the gamete plant. It grows from the moss spore.

When the egg is fertilized and starts its growth it develops into another plant. This is the *sporophyte*, or spore plant. It pro-



The egg of the moss plant develops in the archegonium and the sporophyte grows as a parasite on top of the gametophyte. (After Goebels.)

duces asexual spores and not gametes. The sporophyte consists of the stalk growing from the top of the leafy moss plant and the capsule that the stalk bears.

If the fertilized egg fell down from the top of the moss shoot and the stalk that grows from it took root in the ground and stood up by itself, you would have no trouble in seeing that you are dealing with two plants. There are just as truly two plants when one grows as a parasite on top of the other. There is in the moss an alternation of generations. One plant (the gametophyte) produces gametes, and the fertilized egg grows into the other plant (the sporophyte). In turn the sporophyte produces in its capsule spores, which when they germinate grow into the gametophyte. The cycle runs: gametophyte, egg, sporophyte, spore, and then gametophyte again.

Advantage of sporophyte generation. The advantage of introducing the sporophyte generation into the life cycle is twofold:

First, it gives great opportunity for multiplying the plant. Instead of one new plant from one fertilized egg, there is one from

each of the hundreds of spores in the sporophyte capsule. These blow about and grow where there is opportunity.

Second, the light asexual spores are easily blown about and they can withstand drying and other severe conditions better than gametes. Light, dry spores are suited to a plant that lives on the land.

Look on the walls of recently cut roadside banks, or on recently dumped earth, for a greenish growth. This is probably moss protonema; or it may be protonema and very young, leafy shoots. In biology we must not rush to the conclusion that every structure or function has been planned for a definite purpose and is of immediate use to the plant or animal possessing it. In general, however, animals and plants are adapted to the world in which they live, and the moss sporophyte is a successful device for spreading the plant.

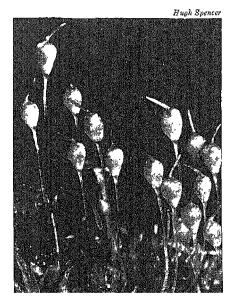
Ancestral structures. Have you wondered about the cilia on the sperms? If plants are adapted to their environment, why does the moss have swimming male gametes, when it lives on the land and often where there is no water except droplets of dew or rain in which they can swim?

The presence of the cilia on the sperms of a land plant is explained on the theory that "ontogeny repeats phylogeny." This is the scientific way of saying that each higher plant or animal in its development "climbs its family tree"; that as it grows from the egg or spore it goes through stages like those its

ancestors passed through as they developed from lower to higher forms (page 134).

When the moss asexual spore germinates, as the first stage in the gametophyte it produces the protonema, which is very like a branching, filamentous alga. The moss is supposed to have had such an ancestor. In the same manner

Capsules on the tips of moss sporophytes. The many light spores produced in the capsules give opportunity for the multiplication and wide distribution of the plant.





Peat moss growing in a bog.

Hugh Spencer

the swimming sperms of the moss are supposed to point back to an ancestor that led an aquatic life.

Peat moss. The only mosses that have any direct economic importance are the sphagnums (sfåg'nums). These are of a different family from the other mosses and are much larger than any of the others. Their pallid growth accumulates in bogs and stagnant swamps, especially in the arctic and temperate regions. A whole pond or bog may be filled with sphagnum moss, the plants dying below and continuing their growth above. These sphagnum accumulations are the peat of which you have read and which you have perhaps seen. In some countries it is dug out, dried, and used as fuel. It is employed as packing material for plants shipped from nurseries and greenhouses, and as litter on poultry-house floors. It is valuable chiefly for its water-absorbing power.

The liverworts. "Wort" is the old Anglo-Saxon word for plant. The liverworts are the "liver plants." They got their

name when herb doctors flourished and made infusions from these little plants as a supposed remedy for diseases of the liver. The liverworts are simpler than the mosses. Like the mosses they have a sporophyte and a gametophyte generation. Some of them grow floating on water; more of them exist as tiny, flat, leaf-like plants on mud and wet soil; some grow, especially in the rainy tropics, on rocks and trees. The largest of them may be a few inches in length and the smallest are hardly as large as the finest moss.

In your laboratory work you may have an opportunity to examine some different kinds of liverworts. A good place to look for them is in a greenhouse, in very wet shady places in a deep ravine, or on the moist banks of a woodland stream.

Mosses and liverworts are simple plants, but one of them is composed of hundreds of cells. Many of them grow only in moist locations. Like frogs, these forms are not far from a water life. Yet in the larger mosses and liverworts we find rhizoids that serve the little plants as roots. In the mosses we find leaves to display the chlorophyll to the light. We find asexual spores that withstand drying and spread the plants by being blown about. In many mosses we find in the whole plant a remarkable capacity to withstand cold or drying, which enables them to serve as pioneer plants that form soil and accumulate humus in cold regions and in rocky areas. The bryophytes are small, but they have started on a land life and as soil builders the mosses have a real place of importance in the biologic scheme.





PROBLEM TWO

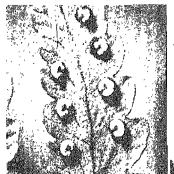
What Are the Chief Characteristics of the Pteridophytes?

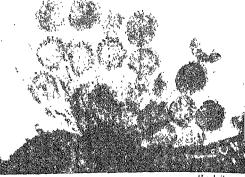
The pteridophytes include the ferns and their relatives. There was a time when they dominated the vegetation of the land, but now the place of prominence has passed to the seed plants. Of the living pteridophytes the ferns are the most important. There are still more than four thousand kinds of them in the world and they are an important enough part of the earth's vegetation for everyone to be familiar with them. We shall study a fern as an example of the pteridophyte group, merely mentioning the other members of the phylum. You will remember that some of the old-time pteridophytes were discussed as plants of the coal period (pages 153–156).

The fern stem. In the tropics some of the ferns (the "tree ferns") have tall upright stems; but most of our temperatezone species have stems that grow horizontally and remain underground. All we see of the fern plant is the long leaves. In the common ferns the stem is usually very short and the leaves grow out from it in a cluster; but as we have seen, Pteris has a long, branching stem with the leaves scattered along it some distance apart (page 524), and Polypodium also has a stem of some length (page 884). In either of these forms it is easy to see the relation of stem, roots, and leaves.

The fern leaves. As soon as a plant reaches any considerable size it has the problem of getting a large area of green tissue exposed to the light. There are many cells to be fed and much chlorophyll must be put to work. The moss gametophyte solved the problem by throwing out thin plates of green cells (the leaves) along the sides of the stem. The fern has adopted the same plan, but its leaves are much bigger and longer and in most ferns they

The photograph at the top of the opposite page shows tree ferns in Tasmania; the lower one, ferns in a Pennsylvania forest. Both of them show the long fern leaves.



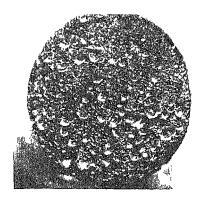


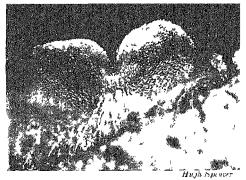
Sori on the back of a fern leaf (left) and fern sporangia photographed through a microscope. You will find scores of sporangia in each fern sorus.

are branched and divided up into leaflets. The fact that the large, feathery leaves are pleasing to our eyes is of no importance to the fern, for ferns are not interested in beautifying the world for us. From the point of view of a plant the leaves are factories for making the food necessary for its life.

Spore production. The large green leaves of the fern are food-making organs, but this is not their only function. On their backs they produce asexual spores, which are developed by cell division in little sporangia. In Pteris the sporangia are found in great numbers under the crimped or folded-over edges of the leaflets. In other ferns they may be collected in clumps which as they ripen show as small, round brown spots called sori (singular, sorus) on the backs of the leaflets. In still other kinds of ferns the sporangia are found only on a certain leaf or branch of In these the spore-bearing leaf or branch may lose its green appearance and look more like a brown head of seeds.

Under a microscope you will have no trouble in seeing the sporangia. They are flattened somewhat like a watch and stand out on a stem. They have very thin walls except for a single longitudinal ring of thick-walled cells. This ring of heavy cells is called the annulus. When it ripens and dries it breaks on one side and straightens out much as your front finger moves when you straighten it out from a flexed position. When the annulus straightens out, it tears the delicate side walls of the sporangium and releases the spores.





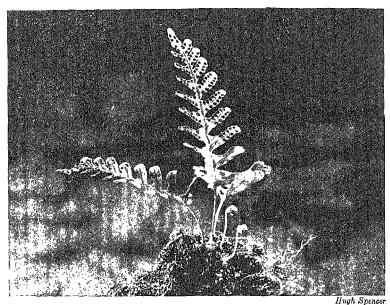
At the left fifteen hundred young fern gametophytes are shown. At the right is a single gametophyte greatly magnified. The under surface and rhizoids are shown.

Germination and growth of fern spore. What becomes of the fern spores? They grow into new fern plants, but not the kind of fern plants that you know. The young plants are little green structures, scale-like and heart-shaped, no larger than your fingernail.

When a fern spore falls in a place favorable for growth (as on moist woodland earth or on a moist rock or log), it germinates. A short green filament three or four cells long is formed. The little plant looks as if it would develop into something like a green alga filament or a moss protonema, but soon it begins to grow sidewise as well as lengthwise. It develops into a flat heart-shaped body that looks like a very small liverwort. It is called the fern *prothallium*. It has rhizoids as mosses and liverworts have.

Alternation of generation in fern. The fern prothallium is the gametophyte. On its lower side it develops archegonia and antheridia, and in these eggs and swimming sperms are produced. When the eggs are mature, the necks of the archegonia open and the sperms manage to swim over to them and into them; thus the eggs are fertilized. Then the eggs are ready to grow into new plants. As in the moss, the egg germinates in the archegonium. The young plant into which it develops quickly strikes root in the soil and grows into the large feathery-leaved plant that we know as the fern.

As in the moss, there is an alternation of generations in the

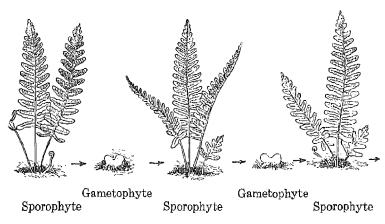


Polypodium, a small fern that often grows on trees and walls. The leaves of all ferns unfold in the manner here shown.



Osmunda, the largest of our ferns. It grows in moist places and the leaves may reach a length of 4 or 5 feet.

THE FERNS 885



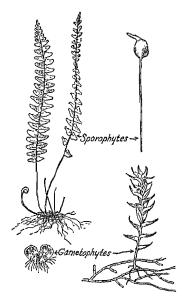
Alternation of generations in the fern.

fern. The little green prothallium produces eggs and sperms. It is the gametophyte — the gamete plant. The fertilized egg on this plant grows into a large-leaved plant. This is the sporophyte. It produces on its leaves asexual spores which develop into the gametophyte. Gametophyte, fertilized egg, sporophyte, asexual spore, and then gametophyte again.

Sometimes even when we look at the two generations of the fern we have difficulty in realizing what a strange state of affairs exists. Suppose an elephant gave birth to some little animal the size of a spring peeper or a mouse and that the offspring of this little animal was an elephant. Such a condition would be similar to that which we find in the fern. We find a comparable alternation of generations in animals like the fluke (page 573) and the hydroids and jellyfishes (pages 798–799).

Correspondence between moss and fern. To what part of the moss plant does the little gametophyte of the fern correspond? To the protonema and the leafy shoot. These grow from the asexual spore. The leafy shoot of the moss produces the gametes.

To what part of the moss does the leafy fern plant correspond? To the stalk and capsule that stands up on the top of the leafy shoot. If you could set the moss sporophyte out in the ground,



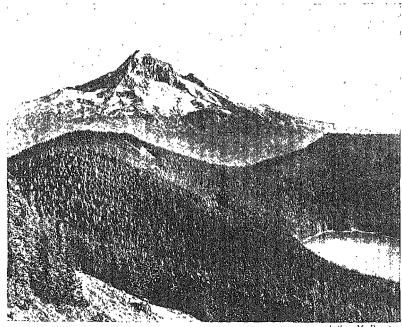
Correspondence in the moss and the fern.

increase its height to 2 or 3 feet, and give it roots and green leaves, you would have something like the sporophyte of the fern.

There is no place in the whole plant kingdom where among living forms there is such a great jump in development as there is between the sporophyte of the moss or liverwort and that of the fern and other pteridophytes. In the moss it is a slender stalk with no leaves and no roots, parasitic on the gametophyte, and with only one sporangium (the capsule) on its top. In the fern we find the sporophyte a large independent plant. It has highly special-

ized tissues; its body is differentiated into roots, stem, and leaves, and it produces sporangia and spores to a number greater than we can count. In the fern the gametophyte is simple and the sporophyte is the main plant.

The other pteridophytes are the club mosses and equisetums. Like the ferns, they reproduce by spores and there is an alternation of generations in them. Brief descriptions of these plants will be found in connection with the account of the coal plants and on page 996.



Arthur M. Prentiss

Conifers on the slopes of Mount Hood. The conifers are especially valuable because from regions of cold, from mountains and swamps, and from areas of poor soil they furnish a great lumber supply.

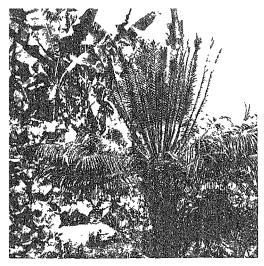
PROBLEM THREE

What Are the Characteristics and Groups of the Gymnosperms?

The gymnosperms are the first great division of the seed plants. They date back to the Paleozoic era when Cordaites represented them in the coal swamps (page 155). The living gymnosperms are woody plants and the important ones are trees. There are no gymnosperms among the small plants of the roadsides and fields.

PRINCIPAL GYMNOSPERM GROUPS

There are three principal divisions of the gymnosperms. These are first, the *cycads* (sī'kāds); second, the *yews and their relatives*, a group of evergreen trees found chiefly in the southern



A cycad. The cycads have short unbranched trunks and palm-like leaves. They grow in the tropics and subtropics.

hemisphere and represented in Europe and Asia by the yew; and third, the conifers—or cone-bearing trees—like the pine, fir, and cypress. We often speak of the conifers collectively as the evergreen trees.

The cycads. The cycads have short, thick, unbranched trunks and long leaves. They resemble low palms and are an old group that was most

abundant when the dinosaurs were the dominant animals of the land. The kinds now living are tropical and semitropical plants; some of them have their seeds on the leaves and some have them in cones. They produce their pollen in cones, like the pines and other conifers, and as in all the gymnosperms the pollen is wind-borne. In Florida and in parts of California cycads are common dooryard plants.

The yew family. The yews grow in temperate climates and in our country are used as ornamental plants. The scales on which the seeds are produced become fleshy and bright so that the little seed cones appear like small berries. Members of a genus closely related to the yews (*Podocarpus*) grow abundantly in Australia and in the mountains of South America. They have tough evergreen leaves that in some species are spiny.

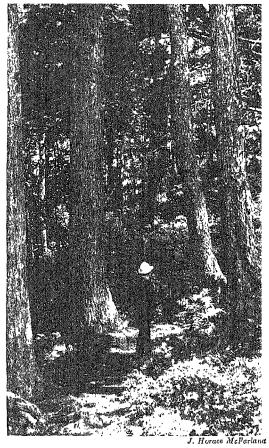
The conifers. The great group of gymnosperms is the conifers. Here belong the pines, cedars, spruces, firs, hemlocks, the deodars (dē'o-dars) and cryptomerias of Asia, and the redwoods and Big Trees of our Pacific coast. The group is a tree alliance. Most of them are evergreen, but the larch (tamarack) of the North and the cypress of the Southern swamps drop their leaves when winter comes.

THE GYMNOSPERMS

The conifers are valuable for their lumber, and they cover much of the colder part of the temperate zone. They are found also on sandy and less fertile soils. As the name indicates, the conifers produce their seeds on the scales of cones. In a few species (as cedars, arbor vitae) the scales of the cones become fleshy and form small "berries."

REPRODUCTION IN THE GYMNOSPERMS

Seed production in the gymnosperms differs in a number of ways from the method we have studied in a flowering plant (page 128). The ovules—young seeds—are not enclosed in a pistil, and the pollen



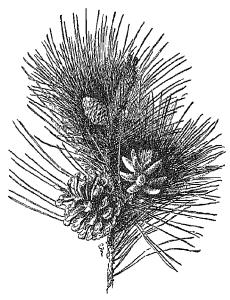
In a hemlock forest in Pennsylvania. The long trunks are characteristic of the conifers.

is wind-borne. The pine produces its seeds in a typical gymnosperm manner and its reproductive methods may be studied as typical of the gymnosperm way.

Seed production in pine. The pine has two kinds of cones, the *staminate* cones which produce pollen, and the *carpellate* (kar'pe-lāt), which bear the seeds. A cone is a branch, and the scales on it are leaves that have lost their chlorophyll and are devoted to reproductive work. A single scale on the staminate cone is called a *stamen* and on a carpellate cone a *carpel*.

Each scale, or stamen, on a pollen cone has two pollen sacs. In the clusters of small cones the yellow pollen is produced in such abundance that sometimes in pine-clad regions it falls as "sulfur showers." In the carpellate cone two ovules develop on the upper surface of each scale. Within an ovule an egg is formed, and this is fertilized in the following way.

When the carpellate cone is young the scales stand open and the pollen that is blown about by the wind catches on their upper surfaces and slides down to the lower ends of the ovules. Then the scales close together tightly, as you can see on a half-grown cone, and the pollen tube starts to grow toward the egg. When it reaches the egg fertilization is accomplished. Then the embryo develops within the seed. When the seeds are mature the scales of the cone open and the seeds escape. Each seed has a wing made of a thin layer split from the face of the scale. Borne by the wind, the offspring of a tall pine travel far be-



Cones of the Austrian pine. On the left below is a 2-year-old carpellate cone that has opened and discharged its seed. Next above on the left is a 1-year-old carpellate cone and at the top two young carpellate cones. On the right is a cluster of staminate cones.

fore they come to earth.

Improved method of securing fertilization. For a land plant the pollen and ovule provide an improved method of securing fertilization of the egg. In the pine there is no swimming of malegametes to the eggs: the pollen grains are blown by the wind to the ovules and the pollen tubes grow down and release the sperms in contact with the egg. The pollen grain is a hard little body that can withstand drying (as the sperms cannot) and is adapted to travel



Staminate cone of pine



Stamen with two pollen sacs



A winged pollen grain

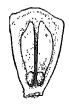
by air. The seed is an adaptation to land life and to a structure that permits plants to reach a large size. As you will readily see, antheridia and archegonia would be out of place on the tips of the branches of a large tree.

Other advantages of the seed. In addition to the improvement that the seed brought in the method of fertilization, plants gained in the seed habit several other advantages. One advantage is that the seed provides sufficient food to allow the embryo plant to grow for some time and to reach a considerable size before it must provide its own nourishment. This helps it in getting itself established in the world. In the seed the egg is fertilized and begins its growth in a structure that is still in contact with the parent plant, from which it can receive food. By the seed plan, the perilous little independent gametophyte generation of the fern that can grow only in sheltered places is abandoned.

A second advantage of the seed is that it enables the plant to pass through periods of drought and cold. On each side of the equatorial rain belt there is a great zone where the seasons are wet and dry. Here the earth is covered with annual grasses that grow during the rainy season, produce seed, and die. The seeds



Carpellate cone of pine



Scale of carpellate cone



A winged seed

rest through the dry season and germinate when the rains come; then the plants run their life courses before the moisture again fails.

Hundreds of plants in the colder parts of the earth carry on life on the same plan. During the summer they grow and produce seed; when autumn comes they die. They cannot resist cold, but their seeds can. The seeds carry the plant through the period of ice and snow, and when sufficient warmth returns the embryo seedlings wake up and a new generation of plants takes root in the land. Without seeds, hundreds of species of our plants would be wiped out in a single year.

Many animals hibernate. We might think of the young plant as hibernating in the seed. The pollen tube reaches the egg in the ovule and the egg is fertilized. It begins to grow and the development of the baby plant has begun. Then the parent plant throws a hard covering about the seed and the growth of the embryo stops. It becomes quiescent and waits until favorable conditions for germination come.

In addition to the gymnosperms we have mentioned there are a few species of tropical woody vines, *Gnetum* (nē'tum); a few kinds of leafless desert shrubs, *Ephedra* (ĕ-fē'dra); and a curious plant, *Tumboa* or *Welwitschia*, that grows somewhat like a woody radish in the Kalahari Desert and has two long tough leaves that are whipped about by the desert winds. These plants have survived from a time when the gymnosperms were the chief land plants, and they show their relationship to other living gymnosperms only by the way they produce their seed.

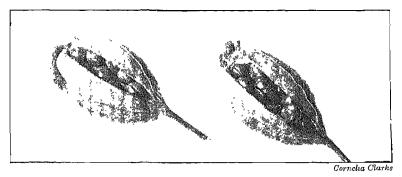
PROBLEM FOUR

What Are the Characteristics and Groups of the Angiosperms?

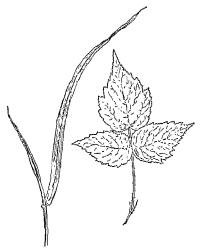
The broad-leafed deciduous trees, the grasses, and the flowers and weeds of the fields are angiosperms. All our crop plants except mushrooms are angiosperms. The angiosperms are the land plants of today. There are fewer than 1000 species of gymnosperms; of angiosperms more than 100,000 species have been named.

Seed production in angiosperms. In the angiosperms the seed does not lie on the open face of a carpel, but is enclosed in a seed vessel, or ovary. A familiar example of such a seed vessel is the pod of a pea or a bean which, like the scale of a pine cone, is a modified leaf. The midrib extends down one side of the pod, and what represents the two edges of the leaf are fastened together down the other side. Some ovaries are made of a single carpel and some of several carpels fastened together. A tulip or a lily has an ovary made of three carpels and the ovary of an apple is composed of five. As you study flowers, and sometimes fruits, you can judge from the divisions of the ovary or perhaps of the stigma how many carpels went into the making of the vessel for the seeds.

Groups of angiosperms. The two great divisions of the angiosperms are the dicotyledons and the monocotyledons. You



The word "angiosperm" means hidden or covered seed. The angiosperms produce their seeds in pods.



Parallel-veined and net-veined leaves.

can distinguish dicots from monocots by their leaves. The dicots have net-veined leaves and the little veins end open among the cells. Practically all the monocots have parallel-veined leaves, and the veins end in another larger vein that runs around the margin of the leaf. The dicots have open venation and the monocots closed venation.

The dicotyledons. The dicots began as trees. The magnolia family, to which the

tulip tree (yellow poplar) belongs, is an old one and the conelike clusters of seed remind us of the gymnosperms. The sweet gum and the sassafras, too, are ancient trees; and in the catkins of many of our forest trees and shrubs and of willows and poplars there is an arrangement not so far from the conifer way. In most of these older dicots the stamens are in a separate flower from the pistil. In most of them there are no petals, no perfume, no nectar. Insects do not carry the pollen, but as in the gymnosperms it is wind-borne. The oak, ash, elm, beech, walnut, and hickory require no bees to pollinate their flowers. All of them, however, have the seeds enclosed.

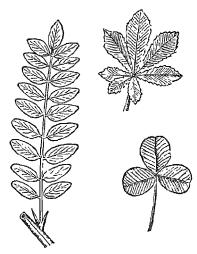
On the other hand, some of the tree dicots belong to families that have developed showy flowers. The locust, horse chestnut, and catalpa, not to mention our fruit trees, are examples of flowering trees and there are many families of tropical dicot forest trees that have bright flowers.

The dicot herbs are newer than most of the trees and are found chiefly in the temperate and colder parts of the earth. Some of them (especially many weeds) have inconspicuous blossoms, but most of them have bright flowers and are insect-pollinated. Most of the flowers and weeds of the fields and roadsides and

most of the vegetables of our gardens are dicot herbs. Many of these herbs are annuals that pass through the winter in the seed.

Types of dicot leaves. Dicot leaves may be simple or compound. The simple leaves may be lobed, as they are in the maple and oak, but the blade is all in one piece. In compound leaves the lobing is so deep that the blade is cut into separate leaflets.

Compound leaves are of two kinds, pinnately compound and



Pinnately and palmately compound leaves.

palmately compound. In a pinnate leaf (Latin pinna, feather) the leaflets are arranged along the sides of the main vein of the leaf. In a palmate leaf (Latin palma, hand) the leaflets all arise from one point as the fingers arise from the palm of the hand. The illustration will make clear the form of these types of compound leaves.

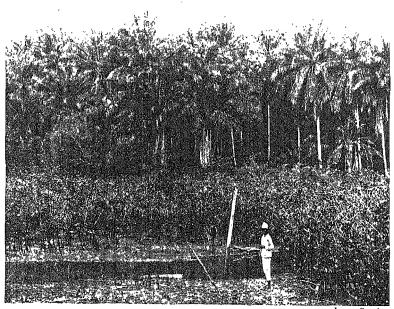
The monocotyledons. In respect to flowers the monocots begin very simply. Cattails are monocots. The grasses and grains are monocots. Jack-in-the-pulpit and skunk cabbage are monocots. The palms are monocots and they have inconspicuous flowers. But many of the monocots do have bright flowers, among them the lilies and their relatives (as tulip, hyacinth, narcissus, amaryllis, iris, gladiolus), the cannas, and the orchids. Many of these bright monocots are spring plants of the woods that come up from underground bulbs and blossom before the leaves appear on the trees. They have three or four petals, never five.

The dicots furnish man with lumber; the monocots are the chief producers of food. Without the palms (coconut, date, and sago palms), the banana, and sugar cane, the tropics would be

without their chief food plants. Without the grasses and the grains the human population of the temperate region would be but a fraction of what it is now. Only after the monocots appeared did the mammals become abundant on the land. The grasses made possible the great flocks and herds of grazing herbivora, and the grains gave man an abundant supply of dry food that would keep when stored for winter use.

Advances in angiosperms. In their anatomy the angiosperms have made some advances over the gymnosperms, but their big advance was in the introduction of flowers. In their lower orders they depend on wind pollination, a hit-or-miss method by which all but a small percentage of the pollen is wasted.

The upper families of the angiosperms place brightly colored

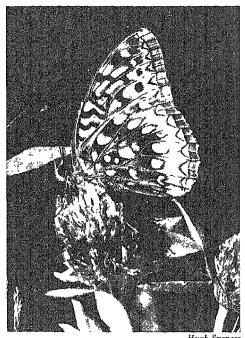


James Sawders

Palm trees on the seashore in Brazil. Next to the grasses the most important monocot family is the palms. Some of them are resistant to salt water, which makes them especially valuable in coastal and island regions.

flower parts about their stamens and pistils. They bait these blossoms with nectar and scent them with perfumes that attract insects to them. The insect visitors get the pollen on their bodies and transfer it to the pistils of other flowers. In their arrangements for insect pollination the angiosperms made the final advance in reproduction in the plant line.

Not all the success of the angiosperms is owing to their method of seed production. They are more adaptable than the



Hugh Spencer

In their arrangement for insect pollination of the flowers, the angiosperms made the final advance in reproduction in the plant line.

gymnosperms, producing types of plants fitted to all climates and all locations. Some of them have perfected highly effective methods of vegetative propagation, a method little used by the gymnosperms. They have developed the deciduous and annual habits which fit them for regions with seasons of cold and drought. As the mammals are the newest and most highly developed of the land animals, so are the angiosperms the newest and most highly developed of the land plants.



Ewing Galloway

Spanish moss on a live oak in southern Louisiana. The region is one of abundant rainfall, but the moss grows under xerophytic conditions because it has no connection with the earth.

PROBLEM FIVE

What Are Some of the More Important Ecological Relationships of the Land Plants?

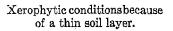
Many environmental factors exert their influence in the life of a land plant, but we shall confine our present study to a consideration of water, light, and temperature relationships. Since the primary purpose of the problem is to enable you to interpret what you see in the plants about you, attention will be given to the effects on the plants and not to the way the effects are produced. During the study it is well to hold in mind that the environment of an organism may be influenced both by general climatic factors and by local conditions. A plant may have a scant water supply either because it grows in a desert or on a rock. It may have a weak light supply either because it grows in a region of fog and cloud or in forest shade.

WATER RELATIONS

So important is water in the life of plants that the land plants are classed as *xerophytes*, *mesophytes*, and *hydrophytes*, according to their adaptation to the water supply. These terms are from the Greek and define themselves. *Xeros* means dry and "phyte" is from *phyton*, plant. Literally, a xerophyte is a dry plant. *Mesos* means in the middle or between and a mesophyte is a middle or medium plant. *Hydro* is from the Greek word for water and a hydrophyte is a water plant. As the terms are used, they refer to plants adapted to dry, medium dry, and wet habitats.

Xerophytes. Desert plants are xerophytes. The lichens, mosses, and other plants that grow on trees or rocks also are xerophytes. Rock-garden plants are xerophytes and xerophytic plants are found on the steep slopes and exposed points of mountains, where the soil is thin and the water drains away. Sandy

soils have little waterholding power and locations on these are xerophytic. Extreme xerophytic conditions prevail in the winter when the water in the earth and in the vessels of plants is frozen. Only plants that can live with a small water supply can hold their leaves during winter cold; so the evergreens of cold climates are xerophytes. Observe plants as they grow in the fields, by the roadsides, and in gardens, and you will note some with the ability



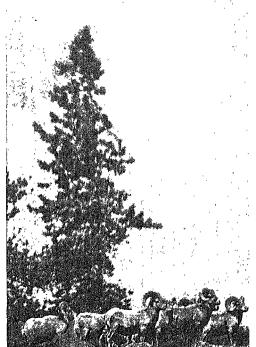


Photo by Blickensderfer, courtesy Nature Magazine



Nature Magazine

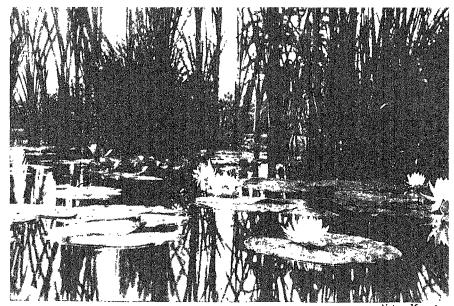
Extreme xerophytic conditions because of cold. On page 541 xerophytic conditions because of lack of rainfall are shown.

to grow with only a meager water supply.

In deserts, where the light is bright and the temperature high, only xerophytic plants are found. Some of these have deep and wide-ranging root systems that draw water from a great extent of soil. They have small and thick leaves or no leaves. All of them have great water-retaining power. Plants like the cacti, the Joshua tree (a yucca), the mesquite, and the sagebrush of our Western plains live and grow where mesophytic or hydrophytic plants would die at once.

Hydrophytes. The plants of marshes, swamps, lakes, and ponds are hydrophytes. Water lilies, cattails, and rushes are common examples of such plants. The savannas for which the city of Savannah, Georgia, was named are wide marshy areas that are covered with grass. Over our Eastern and Gulf coastal plain from New York south are great swamp areas covered with white cedar, cypress, gum, and other trees adapted to wet land, and the glacial swamps of Michigan and Wisconsin produce fine forests of arbor vitae.

In swamp water, plants develop a feeble root system capable of feeding up only a scant water supply. Because of reflection from the water, light conditions are intense and transpiration is rapid. In consequence, many swamp plants resemble xerophytes. Some of them are the same species found in xerophytic mountain locations, and many of them have thick, tough leaves.



A hydrophytic society.

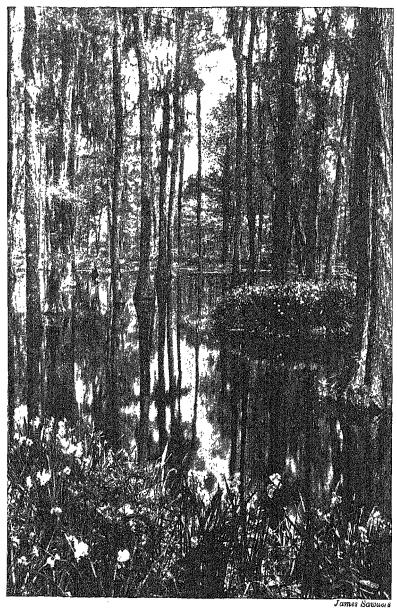
Nature Magazine

Mesophytes. The two great types of mesophytic plants are the broad-leafed trees and the grasses. A third important type, which makes up most of the species of land plants, is the mesophytic herbs. These are the common plants over much of the earth's surface. The soil in which mesophytes grow allows deep penetration of the roots and furnishes an abundant water supply. In consequence, the plant can spread out a great leaf area to the light.

In the rainy tropics and over much of the temperate regions the plants are mesophytes. The deciduous forests of the eastern United States, except the swamp forests, are composed of societies of mesophytic plants. In parts of the country, beech and maple are in the upland forests the main trees. In other areas oak and hickory forests are the prevailing type. The tulip tree, ash, elm, birch, and poplar are other common Eastern forest trees. In the prairies and plains societies the grasses are the chief plants, but other plants are always mixed with them.

LIGHT RELATIONS

Exposure of the leaves of a plant to light is necessary for the manufacture of food. It is expected, therefore, that in plants we

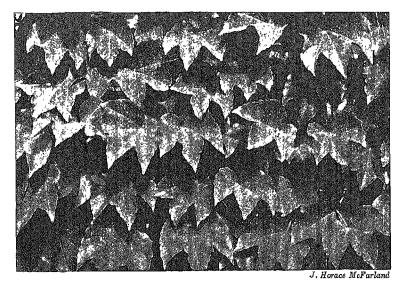


A hydrophytic association in the cypress gardens at Charleston, South Carolina.

shall find many adaptations for placing the leaves so that they will receive the light required to carry on this most important process. A few of these arrangements will be noted here.

Leaf mosaics. Note how the leaves of a vine on a wall or of a dandelion or a plantain on the earth form a mosaic with each leaf so fitted in that it can receive light. Study the accompanying illustration. The placing and turning of each leaf so the blade will receive light is done by the growth of the petiole. If a leaf is covered, as the lower leaves of a rosette are, the petiole will grow in length and push the leaf outward to the light. If light falls on one side of the petiole more than on the other, the cells on the side receiving the weaker light will grow and bend the petiole, thus turning the blade to the light. The leaf mosaic is made by each leaf acting individually to place itself as best it can to receive light.

Leaf arrangements on trees. Trees show great variation in the methods employed in exposing the leaves to the light. Some close-crowned trees (Norway maple, horse chestnut) have a dense layer of leaves about the outside of the crown and no



Leaf mosaic on a wall. Each leaf arranges itself so it will receive light.



A pine with its leaves arranged in tiers so that the light penetrates far into the crown.



A dogwood tree with the same deck arrangement of the leaves that the pine shows.

leaves in the heart. Other trees (elm, birch) are open-crowned with leaves far down the branches toward the trunk. In many trees (sugar maple, beech, dogwood, hemlock) the twigs on the branches grow horizontally but not up and down, so that each branch is a flat sheet. This allows the light to penetrate far into the crown of the tree and permits the arranging of the leaves in tiers, each a mosaic in itself. In many of the conifers the branches are arranged in circles with spaces between them. In coneshaped trees (cedar, larch) the lower branches in their outward growth keep ahead of the upper branches and thus escape being covered.

Size of leaves and fineness of twigs. Trees with large, long leaves have coarse twigs. Trees with small leaves have fine twigs. Either the twigs or the leaves must reach out to all the space in the crown of the tree and if the leaves are long and able to do the reaching for themselves many small twigs are not required.

Trees like the ash, walnut, and ailanthus with their long com-

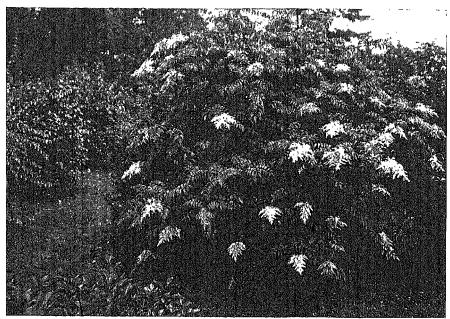
pound leaves have a beautiful appearance in summer, but their branches show coarse and stiff when the leaves are gone. In contrast, trees that have small leaves like the birch and the elm in their winter condition show fine and delicate against the sky. In choosing trees and shrubs for planting about houses, the winter



The leaves of a maple spray arrange themselves in a mosaic through the direction and extent of their growth. Note how the one at the top of this spray reached the light. (After Kerner.)



The fine twigs suggest that when the leaves appear they will be small.



J. Horace McFarland

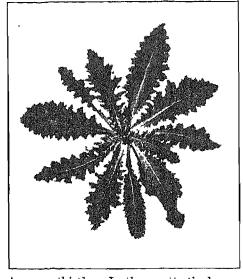
The long compound leaves make us certain that when they fall coarse twigs will be disclosed.

as well as the summer appearance should be taken into account. Trees with few and coarse twigs resist ice storms better than the fine-twigged kinds.

Leaf arrangements in herbs. Two common leaf arrangements in herbs are shown in the illustrations on this and the next page. In one arrangement the leaves are spread as a rosette on the ground. In the other they are spaced at intervals on the sides of an upright unbranched stem. In the milkweed shoot shown in the illustration the pairs of opposite leaves are placed at right angles to each other, giving four vertical rows of leaves about the stalk. Other arrangements are followed in other herbs, but if you will examine upright-growing plants like goldenrod or the wild asters you will find that in all of them the leaves are placed in a systematic manner about the stem and expose a large area of green tissue to the light. Of course there are many branched herbs in which the leaf arrangement is not so simple as has been described here.

The deciduous habit. The deciduous habit in trees may be looked on as a method of getting a wide leaf area exposed to

light during the favorable growing period of the year. In springtime the deciduous tree unfolds a whole leaf expanse and runs a great food factory through the summer months. When autumn comes it drops its leaves and closes down the factory until spring again arrives. This plan is in contrast to that of the evergreens that retain their small tough leaves and carry their food making through the year.



A young thistle. In the rosette the leaves fill the space without covering each other.



A milkweed shoot. As in many other herbs, the leaves are so arranged about the stem that they expose tier after tier of green tissue to the light.

In the parts of the temperate zones where the soil is deep and moist and the growing season long, the deciduous tree grows better than the evergreen. The abundant water supply enables it to support a great crown of leaves, and the long growing season allows it to keep these leaves for so long a time that it can manufacture more food in the summer than an evergreen can produce in the whole year. On the other hand. the evergreen succeeds where the water supply is less abundant and where the winters are long. In sandy soils, steep and rocky mountain slopes, and the far north it is the prevailing tree. vou live in a region of mixed deciduous and evergreen trees, note the locations where each type is found.

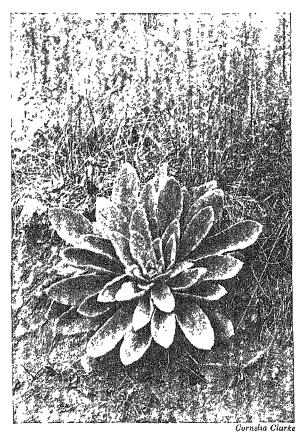
TEMPERATURE RELATIONS

In a previous unit (pages 208–209) we have called attention to various methods adopted by plants for meeting the problems of winter cold. We shall here note some additional adaptations on the part of plants that are exposed to low temperatures.

The rosette habit. Many biennial plants (mullein, evening primrose, shepherd's-purse) and some perennials (plantain, dandelion) grow as rosettes. The leaves pass the winter down close to the ground where they are not exposed to the winds and where they will be more likely to be protected by a covering of snow. At blossoming time the plants throw up stalks that bring the flowers up where they will be found by insects and from which the seeds can be better dispersed. Many of the herbs that grow on high, cold mountains and in arctic regions are rosettes. Their low-placed leaves get the full benefit of the sun's warmth.

Brilliant flowers of arctic plants. The photograph shown on page 101 was taken high in the Alps. The one on page 910 shows a view in our own Western mountains. It is characteristic of flowering plants growing under severe conditions of cold to produce a profusion of conspicuous flowers.

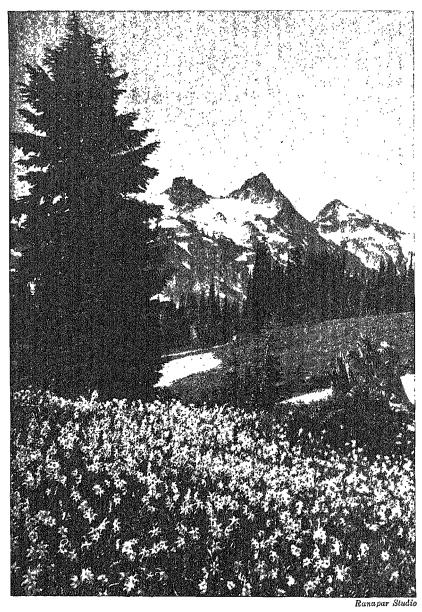
This is interpreted as being an adaptation of these plants to a scarcity of pollencarrying insects. There are few



A mullein rosette. The mullein is one of many biennials that pass the winter in the rosette form.

bees and flies in high alpine (mountain) and arctic locations and the competition among the flowers for the insect visitors is keen. The theory is that only the plants with showy flowers survive because only these are pollinated and produce seed.

Hardiness in plants. Many plants are killed at once by freezing. Other plants endure without injury temperatures far below zero. The ability to resist cold is connected with the way water is held by the protoplasm and to a degree it can be developed in an individual plant by gradual exposure to cold. Seedlings grown in greenhouses and cold frames are "hardened" before

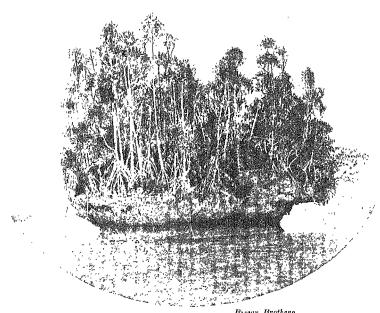


Avalanche lilies in Paradise Park in the mountains of Washington. The brilliance of alpine flowers is supposed to be related to the scarcity of insects in high mountain areas.

they are set in the garden or field. Animal tissues too may have marked hardiness to cold. The feet of small birds in winter must have a temperature below the freezing point and it is said that the ears and fingers of persons who are continuously exposed to severe cold develop remarkable resistance to it.

Needless to say, many alpine and arctic plants have great powers of enduring cold without injury and of growing at very low temperatures. Their ability to resist cold is a marked adaptation to the conditions under which they live.

The greatest seasonal variations that we see in living nature are in the land plants. The appearance of the leaves on the deciduous trees in spring and the coloring and falling of the leaves when summer is ended mark periods when the whole aspect of the landscape is transformed. Great changes in the appearance of fields and roadsides accompany the annual growth and flowering of the smaller plants. These changes are adaptations to the varying environmental conditions that the seasons bring.



Brown Brothers

An example of the way land plants find and occupy any areas open to them. The photograph shows a small coral island (locally called the "flowerpot") in the Pacific Ocean. The plants are tropical monocots (Pandanus) that grow along low coasts and tidal swamps. Their seeds withstand salt water and are dispersed by waves and currents.

IMPORTANCE AND SUCCESS OF LAND PLANTS

The land plants are by far the most prominent biological feature of the land. We live surrounded by them. They furnish us with food and materials for building shelters and for clothing. Their shade protects us from heat and they are the source of most of the fuel that we use. The plant covering of the land is a great sheltering layer in which the animal population feeds and finds its security. Strip it away and the animal life it nourishes and protects would quickly perish.

To those who understand their lives the land plants are marvelous organisms. Without consciousness or mind or ability to move, they adapt and adjust themselves to the varied and varying conditions of the land. They are easier to observe than the land animals because they do not hide away from us. A knowledge of them adds much to the interest of the outdoors.

UNIT COMPREHENSION TEST

- A. Define: ecology; plant society. Where do mosses grow? Describe the appearance of a moss plant. Describe the development of the protonema; of the leafy shoot. Describe the antheridia and archegonia of a moss plant. How is the egg fertilized? Into what does it develop? How does this generation of the moss plant secure food? Define gametophyte; sporophyte; alternation of generations. Make a diagram showing the complete life history of the moss plant. Why is the sporophyte an advantage to mosses? How can we explain the cilia on a moss sperm? What is peat moss? Describe the liverworts.
- B. What plants are members of the pteridophyte group? Explain where and how the spores of ferns are produced. Into what does the fern spore develop? How are the gametes produced? Into what does the fertilized egg develop? Describe the alternation of generations in the fern. What are the corresponding parts of moss and fern plants?
- C. What are three principal gymnosperm groups? What does the word "gymnosperm" mean? (Page 997.) What is a staminate cone? a carpellate cone? a stamen? a carpel? Describe pollination and fertilization in the pine. Why for a large land plant is the pine method of securing fertilization an improvement on the moss and fern method? What other advantages does the seed provide?
- D. What land plants predominate today? How does seed production in an angiosperm differ from the method found in the gymnosperm? What are the two main divisions of the angiosperms? What distinguishes the leaves of dicots? those of monocots? Describe the dicot group. What are the types of dicot leaves? What are some of the important monocot families? What advances over the gymnosperms do angiosperms show?
- E. Name three important environmental factors that influence plant life. Into what three classes are plants divided according to their water relationships? Name several xerophytes. Where may xerophytic conditions be found? What adaptations have xerophytic plants for withstanding drought? Name some plants found in hydrophytic societies. Why do some hydrophytes resemble xerophytes? What are the three most important classes of mesophytic plants? What are the characteristics of mesophytes? How does a leaf find its place in a leaf mosaic? Mention some of the leaf arrangements found on trees. How is size of leaf related to fineness of twig? Describe two leaf arrangements common in herbs. Where do deciduous trees grow best? evergreen trees? Under what conditions is the rosette habit an advantage to a plant? What explanation is given for the brilliance of arctic and alpine flowers?

SUGGESTED ACTIVITIES AND APPLICATIONS

1. Bring in material from a bank or bare ground where the surface shows a greenish hue. Examine under the low power of the microscope for moss protonema and developing leafy shoots. Sketch protonema, bulbils, and partially developed shoots.

Examine on prepared slides antheridia and archegonia. What is produced in each? Make drawings of an antheridium and an

archegonium.

Examine moss that shows the sporophyte generation. Look for plants with young sporophytes like the one shown on page 876. As the sporophyte grows upward the old archegonium is usually carried on its tip.

Make a diagram of the moss life cycle similar to that shown for the fern on page 885.

2. Examine a fern sporophyte. Look for the sori. Place sporangia under the low power of the microscope and examine. Draw a sporangium, showing the annulus and stalk.

Look in a greenhouse where ferns are grown or on moist banks or

logs among ferns in the woods for fern gametophytes.

To grow fern gametophytes, wet a shallow flowerpot and turn it mouth down in a plate of water. Sow fern spores over the top and sides of the pot and cover it with a glass vessel, as shown on page 139.

Watch the development of the spores. Draw a fern gametophyte.

3. Examine staminate and pistillate cones of pine or of some other conifer. Draw a stamen, showing the pollen sacs. Examine pollen under the microscope and draw a grain.

Draw a carpel with the seeds on it.

- 4. List some of the plant societies found in your region, with the plants composing them.
 - 5. Name some rosette plants not mentioned in the text.

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unit 21

James Sawders

SPRINGTIME BIOLOGY

Spring brings a renewal of life's activities. It is the time of birds and flowers and piping frogs. It is emphatically the best of all seasons for the study of biology.

"So then the year is repeating its old story again. We are come once more, thank God! to its most charming chapter. . . . It always makes a pleasant impression on us when we open again at these pages of the book of life."

GOETHE

LIFE ACTIVITY IN THE SPRING

QUESTION FOR CLASS DISCUSSION

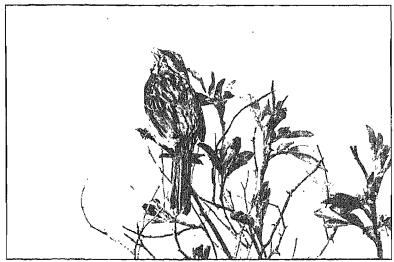
Would you prefer living in a climate with marked seasonal variations, or in one more nearly uniform throughout the year?

OUTSIDE the torrid zone life conditions and life responses change with the coming of the spring. The warmth calls the frogs and reptiles back to activity. The green comes again to the trees and the spring flowers appear. Insects crawl from their hiding places or emerge from their pupal cases or cocoons. Mammals that have hibernated are awake; the birds return. The earth again puts on a cloak of green and another season of life and growth has begun.

Spring is the best of all seasons for studying biology. It is not only the time of greatest activity among living things, but it is also the time when we greet this activity with a freshened spirit after the comparatively blank period of winter cold. In this unit we shall give attention to a number of biological subjects that may be advantageously studied in the spring. There is no connection between these subjects except that they are spring-time topics, and topics that will quicken your interest and widen your general biological view.

Problems in Unit 21

- 1 What are some of the interesting spring activities of the birds?
- 2 What noticeable springtime activity do we find about ponds and pools and along streams?
- 3 What insects are prominent in early spring?
- 4 What are some of the plant families prominently represented among the spring flowers?



American Museum of Natural History

Over a large part of our country the song sparrow furnishes the first bird music of the year.

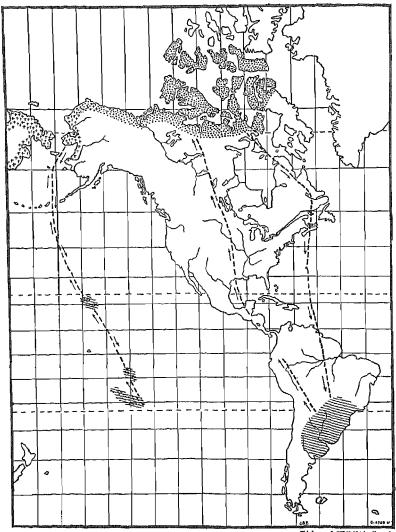
PROBLEM ONE

What Are Some of the Interesting Spring Activities of the Birds?

In the spring the birds return. If they could talk, a little house wren might tell of its winter in Mexico and a bobolink about the marshes of the Paraguay River far beyond the Amazon. Let us begin this problem with a discussion of the always fascinating topic of bird migration.

Migrations of birds. At certain times in late summer or autumn many kinds of our birds start south. Some from the far north winter in our Northern states. Others go on until the Southern states are reached. Others winter in the West Indies or Central America, and fifty species of New England birds go to South America.

What causes birds to decide that it is time to migrate is not definitely known, but they are probably influenced by the length of the day. Without regard to the weather they start



Fish and Wildlife Service

Distribution and migration routes of the golden plover. Adults of the Eastern form migrate across northeastern Canada and then by a nonstop flight reach South America. In spring they return by way of the Mississippi Valley.

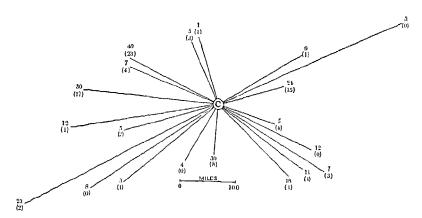
The Pacific golden plover breeds in Alaska and make a nonstop flight across the ocean to Hawaii, the Marquesas Islands, and the Low Archipelago. How without instruments they find the tiny island dots in the vast expanse of water remains a mystery to us.

south and return at very nearly the same dates each year. The smaller kinds work along rather slowly, journeying perhaps 25 miles a day. The timid, retiring ones like the vireos and warblers usually make their migratory flights by night. During the day they rest and feed.

How birds find their way. One theory to explain how birds find their way is the "follow the leader" one. According to this, some of the older birds are familiar with the route because they have been over it before; the young birds follow the older ones that know the way. The manner in which birds of the same species follow the same routes year after year (sometimes not the most direct routes) seems to support this theory. On the other hand, the early-hatched young of some birds start south before the adults, and the ability of homing pigeons and other nonmigratory birds to find their way back home indicates that birds have a direction sense that is unknown to us. Sea birds from islands off the coast of England have been taken 1200 miles to eastern Europe and have returned over a route never traveled before by them or their ancestors. There is evidence that cats. dogs, and other animals also have this direction sense. The illustration on the next page shows the ability of starlings to return from distant places to their home.

Why birds migrate. The necessity for most (but not all) bird migration can be explained by the need for obtaining a supply of proper food. Birds have body temperatures higher than ours (103° or 104° and even up to 110°); their metabolism is rapid; and some of them eat so voraciously that they consume their weight in insects or worms in a day. It is easy to imagine the plight of a flycatcher with such an appetite if it remained in our Northern states during the winter months. No such multitudes of birds as come to us during the summer could find food in our fields and orchards in winter. One of the reasons for the success of birds is their ability in times of famine to fly to distant regions where food abounds.

We cannot say that birds migrate in order to get food. We can say that they migrate and that migration enables them to



350 banded starlings were carried various distances up to 300 miles from a European city and 120 were proved to have returned. The figure above shows the number released at some of the stations and in parenthesis the number that returned. Such experiments prove that even in non-migratory birds there is a definite homing sense.

get food. Doubtless in their migrations they are controlled entirely by instinct, but their instincts lead them to act in such a way that they survive. Whether a bird is conscious of what it does we do not know.

Mating. A few birds (chickens, pheasants, cowbirds) live in flocks without the males and females mating in pairs; most birds are monogamous. Some of them (martins, cliff swallows, weaverbirds, sea birds) nest in colonies, but most kinds place their nests away from other birds of their own species. A few (eagles, parrots, penguins, geese) mate for life, but most matings last only while a single brood of nestlings is being reared. Many of our songbirds raise two broods of young in a season and it is very common for them to change partners between the first and the second brood.

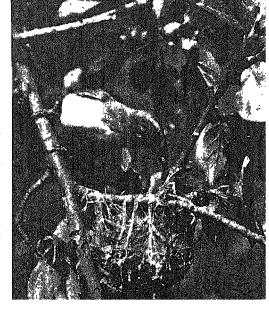
The typical male of the songbirds, when the breeding season comes, finds a nesting ground and announces his claim to it by his singing and by fighting other birds of his own kind and of certain other species. Then he finds a female willing to undertake the rearing of a brood with him and the building of the nest begins.

L W Brownell

Building the nest. The female bird builds the nest, and when the male tries to help her by bringing sticks, grass, feathers, or other materials, it seems that he usually selects the wrong thing. In constructing the nest, the mother bird works with the sureness and expertness of the spider at its web. A robin spins round and round to mold the mud of the nest in circular form with her breast. An oriole hangs a beautifully woven basket so far out at the end of a twig that it is beyond the reach of cats and squirrels. If you watched an oriole through the whole building process you could neither describe its plan nor could you make such a nest yourself. How a young oriole that never saw a nest built can construct one without first learning how, our present knowledge cannot explain.

Bird language. Spring is the time to hear bird calls and bird songs. Rather curiously, in their language the birds have advanced much farther than many animals that greatly excel them

in intelligence. They have various notes which they use throughout the year in calling to each other. rook is said to have forty of these calls, each with its own meaning. Birds use their notes much as we use words in conversation. In addition, the males of many species have songs which they render throughout the mating season. The song is not a love lyric, but a warning to others that this is preempted nesting ground



A red-eyed vireo at its nest. The members of each bird species build nests of a definite type. and trespassers are not allowed. The male bird is staking out a range that will yield a supply of food when the hungry nestlings come.

The notes produced by some birds are wonderfully sweet and pure. Songbirds are able to raise and lower the pitch of the voice and thus pour out a real song. Many birds imitate the songs and calls of other birds, and a number of species by imitating the human voice learn to "talk." No mammal except man can be taught to say a single word, and few of them seem to imitate other animals or man in any way. In their imitative powers and in their use of sounds, the birds are unique.

One peculiar feature of the birds is that the voice box is not a larynx at the top of the trachea, as in mammals, but a syrinx placed at the bottom of the trachea, where the trachea branches into the bronchial tubes. The syrinx containing the vocal cords is placed so far down in the body that a bird (as a chicken or a duck) can utter a vocal sound after its head has been cut off. The notes of some birds are unusually sweet, but in the goose and the swan family the cords on the two sides produce sounds of different pitches, giving a harsh siren-like quality to the voice.

In most species of birds the parents share the task of incubation, and feeding the young keeps them both busy from morning until night. Appetites are huge, growth is quick, and soon the brood is ready to leave the nest. Many birds when the first brood is gone at once set to work to raise a second one. Some consider one brood enough and rest after the first nestlings are old enough to care for themselves. The summer passes and at the proper time the journey southward begins again. The real home of these birds is to the south. Their stay with us represents a mere summer excursion during which they carry out their family raising for the year.

PROBLEM TWO

What Noticeable Springtime Activity Do We Find about Ponds and Pools and along Streams?

The spring rains wash fresh supplies of minerals into the ponds and pools. Algae grow abundantly; masses of Spirogyra are found floating in the water. The food builders are at work and the animal life of the fresh waters enters a season of renewed activity. In this problem we shall study some of the animals that are large enough to attract our attention without our making a special search for them.

THE FROGS

The frogs have passed the winter down in the mud below the frost. At the coming of spring they awake and their voices are one of the early sounds of the new season. The little spring peeper, no bigger than the end of your thumb, climbs a cattail or other support and sends forth a note that is as cheerful and

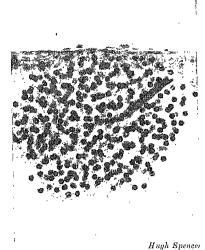
welcome as the warble of the bluebird. The larger species join in, many of them with voices that are remarkable for purity of tone.

It was in the amphibia that the vertebrates first found their voices, and the frogs use their voices more than any vertebrate animals except birds and men. They make their sounds with vocal cords as we do, but in them the air is not drawn into the lungs by expanding the chest (they have no ribs) but by taking it into the mouth and forcing it on downward. Under



Nature Magazini

Hyla, the tree frog, puffs out its throat to call.



Masses of frog eggs. Toad eggs are laid in strings.

water they can croak by passing the air back and forth between the mouth and the lungs over the vocal cords. The bullfrog gets its name from its deep bass voice, which sounds like the bellow of a bull.

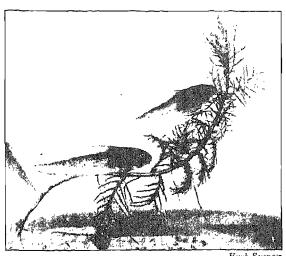
Eggs and early development. The eggs of most frogs and toads are laid in water and fertilized there. In the edges of ponds and pools you will find the frog eggs in masses and the toad eggs in strings. You will find it interesting to bring in some of the eggs and watch them develop. The tadpoles are vege-

table eaters and you can find no better food for them than the masses of Spirogyra that float in the water in the spring.

The egg has considerable food material (yolk) stored in it, and as a chick is built from the food in a hen's egg, so is a small tadpole built of the food that is stored in the egg of a frog. At first there is one nucleus in the egg, but this multiplies by division and a group of cells is quickly formed. At one stage there is a little solid ball of cells; then the ball becomes hollow; then one side folds in to form the endoderm (page 305). The eggs are laid with a coating of transparent sticky material and as the little tadpole develops it is at first enclosed in a gelatin-like capsule. At a very early stage it has cilia over its body which at hatching time help it to get out of the capsule and which beat a current of water over the gills. When it first hatches, a tadpole has two suckers on the lower side of the head by which it clings to a weed, stalk of grass, or other object.

Metamorphosis. Toad tadpoles mature quickly. In about two months they have developed legs and lungs, absorbed their tails, and are ready to hop out on land. The frogs are slower.

The leopard frog remains in the tadpole stage for three or four months. In the North, where the winters are long and the waters cool, the bullfrog may live as a tadpole for three or four years. In the metamorphosis from the tadpole to the toad or frog stage, the lungs develop as a sac or pocket



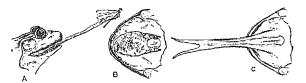
Hugh Spencer

In their watery home the tadpoles lead a precarious existence. Many of them are devoured by large frogs, fish, and the fierce, carnivorous water insects. Only a few of them reach adult size.

leading off from the throat, and legs grow. The tail and gills are absorbed, the mouth is widened, and within the body — in accordance with the change to a meat diet — the intestine is greatly shortened.

Before tadpoles lose their tails and gills entirely they come to the edge of the water, resting where they can use their developing lungs in breathing air. Gradually they work out on land, and sometime after a rain when the air is moist the little toads turn their backs on the home of their childhood and hop off to high land. Most of the frogs remain near water, but the wood frog and tree frogs leave the water completely during their adult life.

The garden toad. The most familiar of all the amphibia is the garden toad. Its skin is rough and warty; its feet are less webbed than those of the frogs; it has no teeth, while a frog has teeth in the upper jaw. It escapes its enemies by hiding away during the day, by its dusty coloring, by flight, and by having a bitter irritating secretion in the skin. Its great enemy is the snake and it is also eaten by owls.



A shows a frog's tongue in action; in B it is folded back within the mouth; and in C it is extended.

The toad feeds chiefly on insects and worms. The sticky tongue is fastened at the front of the mouth and a toad captures insects by flipping the tongue out and drawing them in with it. A toad walks and hops. It creeps stealthily up on an insect at a slow walking gait and when it is near enough it rocks its body forward on its legs and brings in the insect with its tongue.

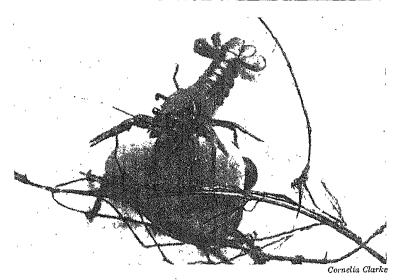
THE CRAYFISH

Another animal that is active early in the spring is the crayfish. You will find it in streams, pools, lakes, and springs. It is easily kept in an aquarium and it is interesting to watch one of them as it moves and feeds.

The crayfish body. The body of a crayfish is segmented, but when you look at it from the back or side the segmentation, except in the abdomen, does not show. The skeleton over the fore part of the body is fused into one large piece which is called the carapace. This covers the head and thorax of the animal much like a shell and it adds greatly to the strength of the crayfish body. The fused head and thorax are called the cephalothorax (sĕf'a-lō-thō'răks).

The head of the crayfish is fixed, but the large compound eyes are movable. They are mounted on stalks which can be turned so that the animal can look in different directions without moving the whole body. The gills are feathery structures under the carapace on each side of the body.

Appendages and movement. Each segment of the crayfish body carries a pair of appendages. The appendages may be very different on different parts of the body, but they are all



An alert and interesting inhabitant of streams and pools. A stroke of the powerful tail will send it backward like a flash.

built on the same plan. Typically, each appendage is composed of a basal segment and two other parts that are attached to it.

The first two pairs of appendages are feelers. Then come a short, hard pair (the mandibles) that work sidewise and chew the food. Back of these are five other pairs that help hold the food and have attachments that fan water back over the gills. Then there are five pairs of long legs, the first pair bearing the fighting pincers and the other pairs being used for walking. On the abdominal segments are five pairs of small "swimmerets," and on the sixth abdominal segment a broad paddle-like pair of appendages that are used with the tail in swimming.

The crayfish can walk forward, sidewise, or backward. It walks best forward and as it does so it holds its big pincer arms out in front. It swims by shooting itself backward with a sudden and powerful forward stroke of the tail against the water. As it swims, the pincers, like the arms of a swimming octopus, trail out behind.

Life of crayfish. In its daily life the crayfish is a walking rather than a swimming animal. It goes away from the light

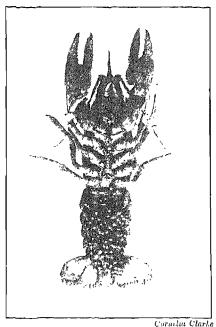


Some species of crayfish burrow in moist lands. They throw up piles of clay, or "chimneys," about the mouth of the hole.

and spends much of its time hidden under projecting rocks, weeds, logs, or other shelter. It backs into its hiding place and watches for animals of a size it can seize and hold with its pincers. feeds on small fish, tadpoles, worms, snails, mosquito wrigglers, and other small animals. It will eat dead organic matter, and if animal food fails it eats plants. It is a night feeder and is especially active at dusk and dawn. The crayfish is itself eaten by the larger fishes, by water birds, and by muskrats, minks, and raccoons.

There are kinds of crayfish that spend most of their lives on the land in low bottoms and pastures, going into the water only when breeding time comes. On low, moist grounds you can find their burrows, often with the earth taken from the hole piled up in a chimney-like structure about the opening. During the day the owner of the burrow rests in it, hidden away, and at night comes forth for food. Many kinds are good diggers and in times of drought they sink deep holes (often down to water level) in which they hide until rain comes. Some kinds can live indefinitely in the air if they can keep their gills moist, as they do by hiding in damp leaves, weeds, or grass.

Reproduction. Cravfishes are unisexual, male or female. The eggs are laid in the spring and are fastened by a kind of glue to the swimmerets of the female. The eggs hatch in from five to eight weeks, but the young do not go free at once. They remain attached to the swimmerets of the mother for about a month after hatching. They moult at least seven times the first summer and the life span is 3 or 4 years. The little crayfish is about a quarter of an inch

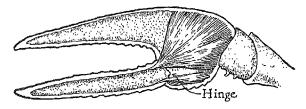


When the female crayfish lays her eggs she lies on her back and rocks back and forth. A sticky fluid is exuded and as the eggs are laid they are glued to the swimmerets.

long when hatched. In a year it reaches a length of perhaps 1½ inches. A full-grown one is 5 or 6 inches long.

Organ of equilibrium. On the basal joint of each of the first pair of feelers is an organ that is called a statocyst. Each statocyst is a small pit lined with short hairs that are connected with nerves. In among the hairs the crayfish places a few grains of sand and then by the way the sand presses on the hairs it can tell when it is right side up. If the sand lies on the hairs on the right side of the pit, the animal knows it is on its right side. If the sand stimulates the hairs on the left side, this gives information that the animal is on its left side. If the animal turns so that the sand rests on the hairs at the bottom of the pit, then its back is up as it ought to be.

The statocyst is made by folding in the skin and when the animal moults the lining of the pit is shed. After this for a time the crayfish has trouble keeping its position in the water, as it has if the statocysts are destroyed.



Like all the arthropods, the crayfish moves by means of muscles that are enclosed within the skeleton. The drawing shows the attachments of the muscle that closes the pincers of the claw.

Internal organs. The mouth of the crayfish is immediately below the stomach and opens into it through a short esophagus. The comparatively large liver is located just back of the stomach, and the two green glands ("kidneys") are found immediately in front of the stomach. The protein wastes excreted by the green glands are discharged through openings at the bases of the antennae. An interesting feature of the digestive system is the gastric mill. The stomach is lined with chitin and on its walls there are horny teeth that rub against each other and grind the food.

The heart of the crayfish is in the upper part of the body behind the stomach. It is a muscular sac which pumps blood through the gills and thence through all the tissues. As the blood circulates through the gills carbon dioxide is given off into the water and oxygen is taken in. The nervous system of the crayfish is of the regular arthropod type. It closely resembles the nervous system of an insect. The crayfish also in its external jointed skeleton and its internal muscles is like the insects. The heaviest of the muscles are those that bend the body, but powerful ones also work the pincers of the claws.

Behavior of crayfish. The animal psychologists tell us that the crayfish is not very intelligent, its behavior being 'largely made up of reflex and instinctive activities." It is, however, a sturdy little animal that adapts itself quite successfully to varied and changing conditions. It eats anything that comes to hand. It is wary and hides from its enemies, but if captured or cornered it fights. No matter how powerful its opponent may be, the crayfish pinches with its claws and scratches with the sharp toes of its walking legs. The crayfish takes life as he finds it and meets the problems that confront him as best he can.

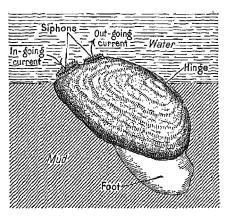
Economically crayfishes are sometimes a nuisance because of their habit of boring through dikes and dams. Some of those that live on bottom lands may eat young corn or other crops. In France they are esteemed for food. In our country, except in Louisiana, they are not much used.

THE MUSSEL, OR FRESH-WATER CLAM

The other animal that we shall study in this problem is the mussel, or fresh-water clam. It is found in nearly all lakes and streams of any size where there is enough limestone in the water for the building of the shell. Like the frogs, the mussels go deep down into the mud in winter. They are active as soon as spring comes, and they send forth their young while the migrations of the

fish are on. There are about ninety species of mussels, divided into two genera. In one genus (Anodonta) the edge of the shell is smooth and in the other (Unio) it is slightly toothed. There are many fresh-water and land snails, but the mussel is the only bivalve that does not live in the sea.

How the mussel lives. The mussel is a "strainer." Like the other

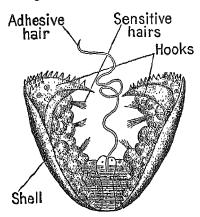


A fresh-water clam, or mussel, embedded in the mud at the bottom of a stream.

bivalve mollusks it gets its food by filtering water through its gills (page 814). The adult mussel stands mouth end down, buried in the mud with only the back tip of the shell sticking out. The cilia beat a constant current of water over the gills and any food materials — small algae, protozoa, bacteria, or particles of organic matter — are caught on the sticky gills and swept to the mouth.

A mussel is not so helpless as an oyster, for it can come up out of the mud, turn the edge of the shell down, and work along on its one muscular foot as a snail does. Its journeys, however, are measured by feet and yards and not by miles. Its adult life is a monotonous one, but it experiences adventure and travel in its youth.

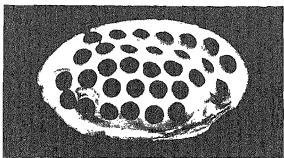
Early life of mussel. The sperms of the male are discharged into the water and are drawn into the mantle chamber



A young mussel or glochidium. At the touch of a fish, the shell snaps shut and attaches the animal to the skin of the fish. Minnows or other very small fish may carry the tiny mussels about. of the female through the siphon. In the mantle chamber the eggs are fertilized, and there the young start their development, clinging to the gills. They develop little shells with hooks on the edges and have a sticky thread hanging out of the shell from the middle of the body. When they are ready, they are discharged from the gills of the mother and settle at the bottom of the stream or lake. Then, if a fish touches the tiny mussel, the shell snaps shut and holds to the fish's skin.

On the fish the young mussel

causes a "pimple" or "blackhead." For a time it lives as a parasite embedded in the fish's skin. It grows and changes its form. Then it drops away from the fish and takes up the life of the adult fresh-water clam. One advantage to the young of



American Museum of Natural History

Shell of a mussel from which buttons have been cut.

attaching themselves to fishes is that the fish carry them upstream and out into smaller tributary streams. Without this method of travel there would be a constant tendency for the eggs and young to be carried downstream and in time the species would doubtless find itself moved down to the sea. Another advantage is that small streams in which the mussels perish by the drying up of the waters in drought years are restocked by the coming again of the fish.

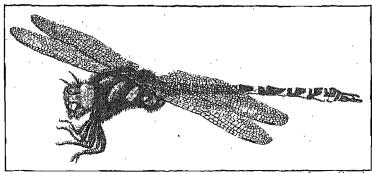
The life history as it has been given above applies to Anodonta, the smooth-edged kind. That of the other mussels is similar except that the young have no hooks on the shell and lodge in the gills of fishes instead of attaching themselves to the outside.

Uses and problems of mussels. The mussel shell is lined with "mother-of-pearl" and the shells of some kinds are used in making pearl buttons. The buttons are made by cutting disks out of the shells. The great trouble in the business is to get enough shells to keep the factories running. The mud that is washed down from cultivated fields into the streams smothers the young mussels. The pollution of streams causes them to die before they leave the gill chambers of the mothers. The building of dams changes conditions in the streams and interferes with the travels of fish. Now the United States government has an experiment station that is working on the multiplication and distribution of mussels, but the supply of shells is rapidly declining. Among the enemies of the mussel are the muskrat, mink,

and raccoon. A muskrat opens the shell by gnawing off the hinge.

Study of mussels. If mussels are found in your locality you should bring some of them in and study them. Feel for the tips of their shells by running your hand over the surface of the mud at the bottom of shallow water. Place them in an aquarium with enough dirt in the bottom to allow them to bury themselves. In the mornings you will probably be able to see the tracks they have made in their journeys during the night. In structure a mussel is similar to a hard-shelled clam. By dissecting one you can easily see the mantle, the gills, the wedge-shaped foot, and the strong muscles that close the shell.

In the spring the sun shines warm in the hollows and low places where streams and pools lie. Pussy willows are likely to fringe the water margins and very early the skunk cabbage appears in the marshy spots. Migratory birds often follow stream courses and about ponds and pools bitterns and herons that do not remain through the summer may sometimes be seen.



Auture Magazine

The eagle of the insect world. It cruises fast and far and lives on other insects that it takes from the air.

PROBLEM THREE

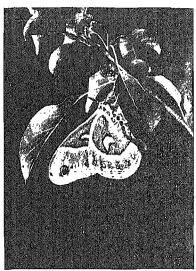
What Insects Are Prominent in Early Spring?

Very early in the spring we see butterflies flitting about. Wasps too are out and an occasional housefly is seen. As the leaves come out on the trees caterpillars appear and by apple-blossom time the codling moth is at hand. Somewhat later large bumblebees fly about and dragonflies and damsel flies skim over the ponds and low grounds. How did all this insect life pass safely through the winter and appear on the spring scene?

Ways of passing the winter. The great majority of insects pass the winter in one of three ways. The eggs live through the winter and hatch in the spring; the insect lives through the winter in its pupal case or cocoon and emerges as an adult in the spring; or adult insects hibernate — hide away in the fall and awake to continue their lives and activity when warm weather again comes.

Insects whose larvae live and feed in the earth or water may pass the winter in the larval stage, but the three ways mentioned above are the ones commonly followed by the insects we see about us in the spring. The honeybee is, of course, exceptional. The members of the colony cluster together in the hive and generate enough warmth to pass the winter in the active state.





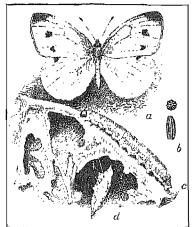
Spencer Hugh Spencer

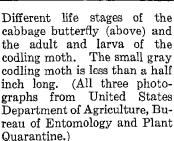
The cecropia moth in its larval and adult form. The large caterpillar is pale green and has six rows of spines along the back and sides. The moth has a wingspread of 6 inches or more. It may be recognized by its large size and the characteristic spot in the center of the wing.

THE BUTTERFLIES AND MOTHS

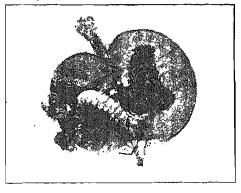
A butterfly has knobs on its antennae and when it lights usually folds its wings together above its back. A moth has feathery antennae and usually rests with its wings spread out. You would find it interesting to examine under a microscope the scales ("dust") from the wings of butterflies and moths and note the differences between them. The butterflies and moths of early spring have passed the winter in the pupal stage.

The cabbage butterfly. One of the widely distributed and very abundant species of butterflies is the cabbage butterfly. It is a rather small species, white with black dots on its wings. It passes the winter in a chrysalis attached to a post, tree, or other object. The butterfly lays its eggs on plants of the mustard family and the larva is the green "cabbage worm" that is such a nuisance to cabbage growers. There are several generations in a season. The individuals that are in the pupal state when fall









comes live through the winter in this condition and appear as butterflies in the spring.

Moths. The codling moth, which is the greatest foe of the apple grower, passes the winter in a cocoon that is fastened to the bark of a tree or in some other place about the orchard. The moth lays its egg near the apple blossom, usually on the calyx of the flower. The egg hatches and the larva usually enters the young fruit at the end away from the stem. There are two or three generations of the codling moth in a season and it requires much spraying or dusting of the trees to hold it in check.

The large sphinx moths, which later in the season hover like hummingbirds over the flowers, winter in large brown pupal cases in the earth. The larvae of these moths are the large green worms found on tomato and tobacco plants and on the leaves of the catalpa tree. The pupal cases are occasionally dug up in gardens in the spring. They may be recognized by the slender projection on one end which encloses the moth's long tongue.

THE DRAGONFLY

The dragonfly is as notable among insects as the eagle is among birds. In spring and summer you will see it and its smaller relative, the damsel fly, about streams and ponds. When at rest the dragonfly holds its wings expanded. The damsel fly folds its wings back along the body when it lights.

Features of dragonfly. The front wings of the dragonfly are set higher on the body than the back ones, and among all flying animals it is the only biplane type. It is so swift that except when cold weather makes it sluggish no bird or bat can capture it, and it can fly backward or upside down. Its eyes are so large that they cover a large part of the head, giving it full vision ahead, to the sides, and above. It feasts on mosquitoes and other winged insects, the larger species even seizing small grasshoppers and butterflies. It may be found a mile from water, searching through woodlands and over fields for its prey. Its size, its powerful biting jaws, its speed of wing, and its fierce disposition make it a predator of the first rank.

Life history. The dragonfly is one of the insects that spend their early life in water. The eggs are laid on a weed or a stem of grass beneath the surface of the water of a pond or of a pool in a slow stream; or they may be dropped on the water as the female flies over it and touches the surface. The eggs



Nymph of the dragonfly.

hatch and develop into *nymphs*, like the one shown at the left. The pond or pool where the dragonfly nymph lives is the home of the larvae of caddis flies, water flies, water boatmen, back swimmers, and other insects. The nymph feeds on these and on worms, tiny fish, crustacea, and those of its own kind smaller

than itself. It is a tiger of the pond from its earliest days. It is dark in color and often covered with a layer of mud which helps to conceal it as it lurks for its prey.

In its early stages the larva gets its oxygen by taking water into the back part of the alimentary canal, where thin plate-like folds in the lining of the intestine serve as gills. Later air tubes develop and the larva breathes by thrusting the fore part of its body out of the water.

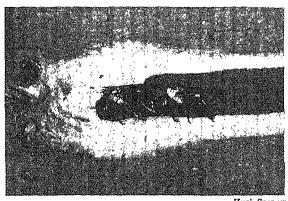
In from less than a year to more than three years, according to the species, the nymph is ready to metamorphose. It then climbs up a weed or other plant to the air, the casing splits along the back, and the adult dragonfly comes forth. After its wings dry it takes to the air. Its common name, "mosquito hawk," is descriptive of its mode of life.

You will note that in the dragonfly there is a complete metamorphosis, but no pupal or resting stage. The larva spends the winter months down in the mud of its pool and when warm weather comes the individuals that have reached maturity pass to the winged stage.

INSECTS THAT HIBERNATE

Houseflies survive by hibernation of the adults. Wasps, hornets, and bumblebees are other insects that go through

the winter in this way, but among them only the females survive. In the fall they hide away and in spring they wake up and start new colonies. Ants also hibernate, but with them workers and all go into a dormant state and



Hugh Spencer

Two carpenter bees asleep in their tunnel in a piece of wood.

the whole colony survives. Ticks and mites, in regard to winter, seem to be in the class with evergreen plants. They are uninjured by cold and when warmth comes again they are ready to take up life where they left it off.

An interesting example of hibernation is furnished by the ladybugs which in some of our Western states gather in colonies for their winter sleep. These attractive little insects belong to the tiger beetle order and they live by crawling over plants and feeding on plant lice and scale insects. In the spring quantities of them are collected as they come out of their winter hiding places. They are sold to the owners of orchards and groves to be released among the trees.

Spring is a good time to begin the study of insects. At this time you can watch wasps starting their nests and if you look for them you will doubtless find cocoons from which butterflies will soon emerge. An especially interesting activity is to dig out a colony of ants and transfer them to a glass house where you can see them work.



J. Horace McFarlana

If in the spring you come upon a group of little green umbrellas pushing upward from the earth, you have found the May apple or mandrake. In May or June waxy white blossoms appear just under the umbrellas. Later the pulpy golden apples the size of pullet eggs are found.

PROBLEM FOUR

What Are Some of the Plant Families Prominently Represented among the Spring Flowers?

The flowers that bloom before the grass comes and the trees put out their leaves are one of the chief joys of spring. Naturally they differ in different parts of our country, and it is not possible for us to describe them flower by flower. Rather we shall discuss some of the prominent families to which these plants belong and mention some forms that are familiar over a wide range. To classify and find the exact names of the flowers of your region you need a key for identifying them and a knowledge of how to use it. The flowers of early spring are especially attractive because many of them are very showy. Possibly this can be accounted for by the fact that pollen-carrying insects are scarce in spring; that a flower must put out a good advertisement or run the risk of being overlooked. Perhaps spring flowers, like those of high mountains, are the survivors that have been successful in getting insects to carry their pollen for them.

GROUPS OF FLOWERING PLANTS

I. Monocots.

Sepals and petals in threes or fours, never in fives. Parallel-veined leaves (except in trilliums and jack-in-the-pulpit family) and closed venation (page 894). Herbs and herbaceous vines.

II. Dicots.

Sepals and petals in fours or fives, never in threes. Net-veined leaves and open venation.

- 1. Apetalous division. No petals.
- 2. Polypetalous division.
 Petals present and separate.
- 3. Sympetalous division.
 Petals more or less joined.

The great groups. The table above shows the main divisions of the flowering plants. The three subdivisions of the dicots are the apetalous (a-pĕt'al-us), polypetalous, and sympetalous groups.

The apetalous dicots have no petals. They have stamens and pistils, but no showy parts to the flower. This division is made

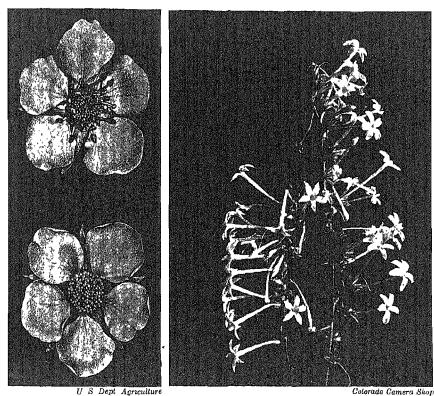


U S Forest Service

Staminate catkins of the hazel. Each catkin is a collection of apetalous flowers.

up chiefly of a great alliance of forest trees whose pollen is windborne and of certain families of weeds with inconspicuous flowers. They are classified by their fruits, leaves, and body characters rather than by the flowers and we shall not concern ourselves with them in our present study.

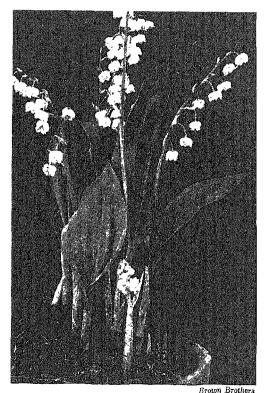
Procedure in classification. In classifying a plant the first step is to decide whether it is a monocot or a dicot. To do this, look at the flowers. If the parts are in threes it is a monocot. If they are in fives it is a dicot. If they are in fours it may belong in



Flowers of the strawberry (left) and of Gilia, a plant of our Western states. They are examples of polypetalous and monopetalous flowers.

either group and you must make your decision from the leaves and stem. Excepting the conifers, all the woody plants (trees, shrubs, woody vines) are dicots. Most of the dicot leaves have petioles (leafstalks) and the leaves of most of our monocots have wide bases that clasp about the stem.

The spring-flowering dicots are mainly polypetalous, but a few are sympetalous. To decide to which of these groups a plant belongs, examine the petals carefully and try pulling them off. If they are joined even slightly at the base the plant belongs in the sympetalous group. If you find where the petals have fallen as the flowers fade, notice whether they drop separately or in one piece.



Lily of the valley, a typical spring monocot.

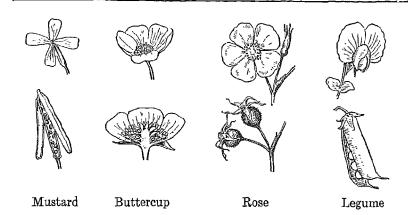
THE SPRING MONOCOTS

Over a great part of our country there is a group of monocots that in both fields and gardens come into early flower. These include the daffodil, hvacinth, crocus, tulip, iris, lily of the valley, star of Bethlehem, dogtooth violet, and the trillium or wake-robin. Most of these monocots belong to the lily family or to families that are closely akin to the lilies. Many of them are bulb plants or have fleshy rootstocks in which food from the previous year is stored. This food is used in the quick

growth of the leaves and flowers. Many of the spring-flowering monocots complete their growth before the grasses and weeds spring up and before the leaves of the trees cut off the sunlight from the forest floor.

Another monocot that comes very early in the spring is the skunk cabbage, which grows in marshy places along streams. has a head of small flowers enclosed in a leaf-like sheath. jack-in-the-pulpit is another member of the family, as are the calla lily and caladium. All these belong to a great monocot family (the Arum Family) that is abundant in the tropics but has only a very few representatives in the temperate zones.

Still another monocot flower that in some places appears in the spring is the lady's-slipper, or moccasin flower. It is an orchid. There are several thousand species of orchids, but only a few of them are native outside the torrid zone.



POLYPETALOUS DICOT FAMILIES

Many polypetalous families are represented among the spring flowers. A botanical guide to the classification will give you the characteristics of the different families in detail. The hollyhock, rose, apple, poppy, water lily, and milkweed are familiar representatives of the group.

The buttercup family. A number of the buttercups are among the early flowers. They are yellow in color. There are many stamens and many little pistils which develop into one-seeded dry fruits. The flower stalk is extended up into the flower and the pistils are placed on this.

Among the many relatives of the buttercups is the hepatica, which grows among the leaves on the forest floor, blossoms very early, and can be recognized by its three-lobed leaf. The anemone or windflower and the columbine are also closely akin to the buttercup group.

The mustard family. The members of the mustard family have small yellow or white flowers. They have four petals placed so that they are supposed to form a cross. On this account the family is called the *Cruciferae* (Latin *crux*, cross). The seed pod has two cavities. It may be flattened (as in shepherd's-purse), but it is usually a slender spike.

The radish, turnip, and cabbage belong to the mustard family; also a number of common wild plants (shepherd's-purse, pepper-

grass, yellow rocket or upland cress). Watch for the characteristic flower and seed pod and you will soon come to recognize the members of the mustard tribe. Most of them have a hot taste.

The rose alliance. The rose family and families that are closely akin to the roses make up a great group of shrubs and trees that are prominent among the spring flowers. The flowering almond, the hawthorn (red haw), the flowering crabs and cherries, and nearly all our temperate-zone fruits like the peach, cherry, plum, apricot, apple, pear, quince, blackberry, and raspberry belong in the general rose group. The flowers of these families usually have an indefinite number of stamens.

Fruits like the apple, pear, and quince are called *pomes*. Single-seeded fruits like the peach, plum, and cherry are *drupes*. A raspberry is a collection of small drupes, and a blackberry a collection of drupes set on a fleshy stem end. The strawberry is a primitive member of the rose alliance that is not far from the buttercups. The expansion of the upper end of the stem (the *receptacle*) makes the edible part. Examine a strawberry and you will see the little dry fruits like the fruits of a buttercup sitting on the surface of the fleshy stem end.

The legumes. The legumes have two great divisions, the mimosas and the ones with flowers like the bean and the pea. The mimosas are in the main tropical and we shall not concern ourselves with them here. The other branch of the family has developed with us trees, shrubs, woody vines, and many herbs and herbaceous vines.

Here belong the locusts and mesquite among trees, the clovers, vetches, lespedezas, alfalfas, peas, and beans. Wistaria is a legume, as are the lupines which are cultivated in gardens and in some regions grow wild and form beds of purple color on the earth. Because of their place in agriculture and the use of some of them as food, the legumes rank high in importance among the families of plants.

The fruit of the legume is a pod, as you have seen in the pea and the bean. The leaf and body form of the different species



Flowers and fruits of members of some representative polypetalous families.

vary greatly, but always the members of the family can be identified by their fruits and flowers.

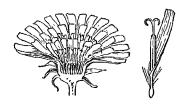
Violets, pinks, geraniums. The violets are of many kinds and widely distributed over the world. They are all easy to recognize by their irregular flowers. One petal is at the bottom, one on each side, and two side by side at the top. Most of the family have whole leaves, but the "bird's-foot violet" has a leaf cut into divisions in such a way that it is supposed to resemble a bird's foot.

The pinks can easily be distinguished by their cut petals. The "rock pink" which makes spots of color on the ground in the spring is not a pink but belongs to the purslane or Portulaca family. The chickweed, which remains green all winter and opens its small white blossoms with the first passing of winter, is an example of a pink.

The wild geranium comes rather late in spring. Its leaf is finely cut, its flowers are a lavender pink, and its fruit has a long pointed beak. Its common name, "crane's-bill," describes the seed pod well. House geraniums have the same beaked pod.

THE SYMPETALOUS DICOTS

The sympetalous dicots are not so prominent as either the monocots or the polypetalous dicots in the flowers of early spring. Yet many specimens of them may be found and some of the families are very prominent by the time summer has come. The nightshade, elder, azalea ("bush honeysuckle"), verbena,





Dandelion

Scarlet sage

The flowers of a composite and of a mint. They are members of the sympetalous group.

phlox, hydrangea, petunia, morning-glory, and many other forms belong here. We shall mention specially only three families, the heaths, mints, and composites.

The heath family. The heaths are a family of shrubs, many of them evergreen. The group includes the kalmia or mountain laurel (ivy, calico bush), the rhododendrons, the huckleberries, and the cranberry. You can distinguish the members of the family from all other plants by the peculiar way the stamens open. Instead of splitting lengthwise as the stamens of most flowers do to release the pollen, they open like a moss capsule by the coming off of a little lid at the top. Some members of the family have showy flowers. The trailing arbutus is one of the heath group.

The mints. There are more than 8000 species of mints and some of them flower in early spring. The members of the family are herbs that have square stems and opposite leaves. Often the foliage is scented. The corolla is two-lipped and is made up of four petals joined together at the base. The fruit appears like four little nutlets inside the calyx, which persists as a sheath about them. The mints can easily be distinguished by their fruits and flowers.

Sage, thyme, and bergamot are mints. Catnip and ground ivy are mints. Peppermint and scarlet sage are mints, and wild species of mints are always to be found. The snapdragons, like the mints, have two-lipped corollas. They belong to a family that is related to the mint tribe.

The composites. The composites have their flowers in heads, often with a circle of "ray flowers" standing like petals about the head. The sunflower and black-eyed Susan are composites. The dandelion, whose blossoms can be gathered in early spring, is a member of the family. Another early composite is the herb Arnica, which very early sends up branching stems perhaps 2 feet high and has on the tips of the stem branches bright yellow flowers.

More than 13,000 composites have been named. The goldenrods, asters, thistles, chrysanthemums, daisies, and hosts of other herbs, weeds, and flowers belong among them. Examine the little individual flowers of one of them and you will find that it belongs in the sympetalous group.

It will add to your pleasure in the outdoors if you can recognize the different kinds of flowers as old acquaintances and call them by their names. Flowers are living things and much biology can be learned by a study of them.

THE CHANGING YEAR

The sun swings back and forth across the equator through an arc of more than 3000 miles. Great changes of climate accompany it on its north and south journeys. Alternately the hemispheres are flooded with warmth and light and left in comparative darkness and cold. The living things must accommodate themselves to the changes and each season is a preparation for one that is to come. The burst of life activities in the spring is but a manifestation of the preparations made by life that has gone before.

It is easy in fall or winter to note the preparations for another year. Cut open a hickory or a horse-chestnut bud. A twig is enclosed with embryo leaves already formed. Split a bulb of a hyacinth or a lily in the fall. The flower is prepared and ready to unfold. Even before the leaves fall the catkins are on the hazel; the dogwood twigs are tipped with buds that hold their coming flowers; the trees in small buds at the bases of their leaves have mapped out their foliage for another year. The autumn ripenings of fruits and seeds are other preparations for a returned period of activity and growth.

We have studied the activities of spring for the interest that they themselves hold, but they are likewise a preparation for the seasons that are to come. The early germination of seeds and the unfolding of leaves enable plants to take advantage of the season of warmth and light for food making and growth. The opening of flowers and the uncoiling of fern leaves mean the production of seeds and spores. The birth of the young of rabbits and squirrels and other animals in early spring gives the offspring the months of abundant food and warmth for growth and permits them to reach sufficient maturity to meet the winter's cold.

The seasons change. Life is continuous and must adapt itself to these changes. The activities of spring are a preparation for summer and those of summer for winter and another year. Life strives and conforms to its necessities and thus survives.

UNIT COMPREHENSION TEST

- A. What stimulus causes birds to migrate? What evidence is there that birds have an unexplained directional sense? What purpose is served by migration? Describe the mating customs of birds. What is the purpose of bird song? Tell about the building of the nest. What calls and notes besides the nesting song do birds use? Where is the bird voice box located and what is it called?
- B. How do frogs pass the winter? How do they make their call? How can you distinguish between the eggs of frogs and toads? Where can you find the eggs? Describe the early development of the tadpole. How old are some of the different kinds of tadpoles when they take the adult form? What changes in structure occur at the time of metamorphosis? What do tadpoles eat? (Page 387.) In what ways do toads differ from frogs? How do toads and frogs capture insects?
- C. Describe the crayfish body. Where are the eyes placed? Where are the gills? Describe the appendages. Tell how the crayfish walks and swims. What do crayfishes eat? Where do they live? Describe the habits of some of the different species. How does the crayfish care for the eggs and young? Describe the statocyst. What is its function? Name the important internal organs of the crayfish. Where does a mussel live? How does it get its food? Where does it pass the first stages of its life? Give an account of its parasitic existence. What advantage to the mussel is in its attachment to the fish? What is the economic importance of mussels?
- D. In what ways do many insects pass through the winter? How can you tell a moth from a butterfly? Tell the life stories of the cabbage butterfly and the codling moth. What are some of the unusual features of the dragonfly? What is the dragonfly larva called? Give an account of its life in the water. Mention some insects that hibernate in the adult form.
- E. What are the three divisions of the dicots? What is the procedure in classifying a plant? Name some of the spring monocots. Give identifying characteristics of the mustard, buttercup, rose, and legume families. Define: pome; drupe; receptacle. What are characteristics of the violets by which they may be recognized? How can you recognize a pink? What structure is characteristic of the geraniums? What are the characteristics of the sympetalous dicots? Name some plant families included in the sympetalous dicots.

SUGGESTED ACTIVITIES AND APPLICATIONS

1. Class project:

Let the class make a list of spring migrant birds observed by the members. Look up where the different species winter and their migration routes. List separately the species that spend the summer in your region and the ones that merely pass through to points farther north.

Watch nest-building activities. Make a collection of written records of actual observations made by class members on the

birds as they build their nests.

- 2. Obtain a copy of Mathews' Field Book of Wild Birds and Their Music (G. P. Putnam's Sons) and learn to recognize birds by their notes.
- 3. Bring in frog and toad eggs and rear the tadpoles. Algae make good food for the developing young.
- 4. Make a careful study of the way a frog breathes, eats, and jumps.
- 5. Bring in crayfish, mussels, salamanders, lizards, small turtles, and snakes. Identify the species and study them.
- 6. Identify and make a list of early spring insects. Record how each kind passed the winter.
- 7. Try to find dragonfly nymphs. The large hinged lower jaw fits over the lower part of the "face" like a mask.
- 8. Collect the spring flowers of the region and with a key identify them. Take note not only of the scientific names of the plants but also of their family characteristics.

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UNIT 22 OUR BIOLOGY COURSE

If we use our biology, it will bring us to a better day.



"I believe invincibly that science and peace will triumph over ignorance and war." Louis Pasteur

THE WIDER VIEW

QUESTIONS FOR CLASS DISCUSSION

What part of a biology course is most important? What part is most interesting?

AN organism is more than the sum of its parts and a forest has a meaning beyond that of individual trees. So your biology course as a whole should have a significance for you that is beyond its individual facts and ideas. Out of it should come a broader outlook on the world, changed mental attitudes, and deeper understandings of many things. The importance of the course to you is to be measured by its effects on you.

One result of your study should be a fuller understanding of what the science of biology itself means. You should now of your own perception know that it is not a definite and finished thing, but a vigorously growing and expanding influence that constantly brings new benefits to mankind. You should see for yourself that the application of biological knowledge to human betterment is a continuous process that always lags behind its possibilities. It should be clear to you that the future is open to indefinite advance; that each discovery widens the horizon and invites the solution of still more interesting and important problems that have been disclosed; that the call for biological workers was never so urgent as now. Out of your study of biology should come a conception of a dynamic and changing world.

The purpose of this brief final unit is to help you realize these wider values of your biology course. The problems of the unit are but extensions of already familiar subjects and ideas. They are taken up with the hope that by placing additional emphasis on them your understanding of biology and your appreciation of its possible uses will be increased.

Problems in Unit 22

- 1 Who are some of the noted builders of biology not mentioned in previous units?
- 2 What recent discoveries promise great advances in biology?
- 3 What are some important applications of biology in the administration of our public domain?
- 4 What are some of the important instinctive social traits of man?
- 5 Is the Constitution of the United States a sound biological document?

PROBLEM ONE

Who Are Some of the Noted Builders of Biology Not Mentioned in Previous Units?

"We are too apt to receive the gifts of science without asking whence they came." T. D. A. COCKERELL

Biology as we know it today was not handed to us ready-made. It has grown out of the accumulated observations, the experimental discoveries, and the thinking of scientific men. for us to have some acquaintance with the men who through zeal and persistent toil have built and extended this great science; so from time to time throughout the course we have mentioned the names of some of them. A few more names will now be added to this list.

ARISTOTLE





Before study in any field can really begin, the material of the field must be explored and surveyed. Aristotle (384–322 B.C.) was the first biological surveyor. As the anthropologists of today are studying and classifying the different peoples of the earth, so Aristotle 2300 years ago was studying and classifying the animals of Greece and the surrounding seas. He is the father of zoölogy.

Aristotle, the great Greek scholar who laid the foundations of zoology.

Aristotle had a great mind, limitless curiosity, and untiring energy. He collected and classified more than 500 kinds of animals, and he also studied the internal structure, the development, and the habits of animals. He was familiar with the growth of the embryo in the eggs of birds; and the following account of the life of the cabbage butterfly, taken from his *History of Animals*, shows how careful an observer he was of insect life:

"The so-called psyche or butterfly is generated from caterpillars which grow on green leaves, chiefly of the raphanus, which some call crambe, or cabbage. At first it is less than the grain of millet, and then grows into a small grub, and in three days it is a tiny caterpillar. After this it grows on and on and becomes quiescent, changes its shape, and is now called a chrysalis. The outer shell is hard and the chrysalis moves if I touch it. It attaches itself by cobweb-like filaments and is unfurnished with mouth or any other apparent organ. After a while the outer covering bursts asunder and out flies the winged creature that we call a psyche or butterfly."

Aristotle was an organizer as well as an investigator on his own account. He conducted a school in Athens and this, unlike any other school up to that time, had a museum and a library and was organized by departments. As in a modern university, each important subject — logic, mathematics, philosophy, politics, natural history — had its own department and courses. With the help of his assistants Aristotle prepared more than 300 books covering practically all fields of knowledge, a work which one writer has described as "the most prodigious intellectual achievement ever connected with any human name."

Of the many works of Aristotle, those on animals were probably the most important. In their preparation Aristotle followed the true scientific method of going for the facts to the materials themselves. The books of course contain many mistakes, but they were the most reliable source of biological information until after the Renaissance. In 1851 a supposedly absurd statement made about the squid was checked by a study of the animal and it was found that Aristotle was correct.

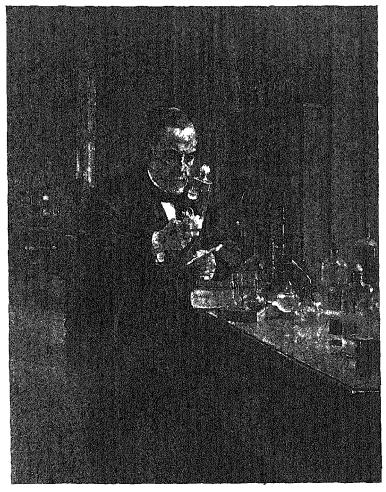
LOUIS PASTEUR

It was a great day for mankind when it was discovered that many of our diseases are caused by minute parasites. With this discovery there is inseparably linked the name of Louis Pasteur. He was a great scientific genius, brilliant alike in formulating hypotheses and in devising experiments to test their truth.

In school Pasteur was attracted by the study of chemistry and he became a teacher of that subject. Early in his scientific career he became interested from a chemical point of view in the changes that go on in decaying and fermenting substances. It was then generally held that the molds and swarms of bacteria found in such substances came into being of themselves, because of the decay processes. Pasteur decided to test this idea of "spontaneous generation" to see if it was correct. He soon found that if flasks of meat or vegetable broth were sterilized by heat and kept covered from the air they remained free from microorganisms and kept indefinitely. If the flasks were opened, bacteria and mold spores from the air fell into them and then grew and multiplied. Instead of being caused by decay, the microörganisms caused the decay. Instead of being generated spontaneously, they grew from other organisms of the same kind.

Passing from this study to a brilliant application of it, Pasteur showed the wine makers of France that batches of wine which turned sour were contaminated with acid-forming bacteria and that these intruders could be destroyed by heating the liquid. Then a call came from the south of France for help in the silk-worm industry. The worms were dying of a disease called pebrine. Pasteur examined the tissues of some of the sick worms with a microscope and found little bodies in them. He decided that the disease was probably caused by small parasites and showed how to prevent it by keeping the healthy worms away from the sick ones and using eggs from only healthy stock. The wine and the silk industries had been saved for France, but Pasteur's work was not yet done.

In the Franco-Prussian War he saw men die of infected wounds.



Louis Pasteur, the supreme biologist. His scientific discoveries and his applications of these discoveries were a benefaction to all mankind.

He examined materials from the wounds and soon convinced himself that the trouble was caused by bacteria, often carried on the hands and instruments of the surgeons. An English surgeon, Lord Lister, accepted the idea and developed the practice of antiseptic surgery. Next Pasteur showed the brewers that their troubles with bitter beer were caused by strains of wild yeasts

that got into the brew, and he helped them overcome their difficulties. Then he was sent to study the disease of cattle and sheep called *anthrax*, which was working havoc in the north of France. He developed a method of protective vaccination, as was recounted on page 8.

In his later years Pasteur turned his attention to rabies and found a way of protecting his experimental animals against the disease by vaccination. In the midst of this work a mother appeared with her son who had been bitten in fourteen places by a rabid dog. Pasteur was reluctant to use the treatment on a human being, but he yielded to the mother's appeal and treated the boy. The results were successful and the work of the great scientist was acclaimed by all.

When we review the work of Pasteur it seems hardly possible that one life should be so fruitful in benefits for mankind. His studies on spontaneous generation placed on a scientific basis the preservation of food by canning. In his discovery of the cause of pebrine he for the first time proved that disease may be caused by a germ. His studies furnished the scientific knowledge which made possible the growth of modern surgery. Taking up Jenner's idea of building immunity through vaccination, he in his own words "extended it far beyond anything Jenner had imagined." The pasteurization of milk—killing dangerous germs by heating to a moderate temperature—was initiated by him, and the Pasteur treatment for the prevention of rabies stands today practically as he gave it to us.

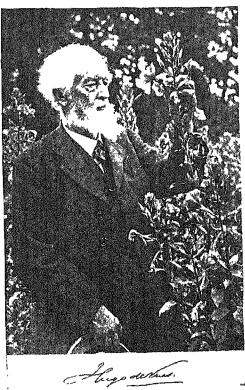
When asked if he did not think he should find a way to become wealthy from his many discoveries, Pasteur replied that he desired only better equipment for his work. In response the people of France built for him by popular subscription the Pasteur Institute, which stands in Paris today. The Master is gone from it, but in its laboratories the kind of work he did is yet carried on. In his last days he said, "There is still much to be done."

HUGO DE VRIES

One of the great questions of biology is that of the origin of species. Formerly it was generally accepted that they arise by small inherited changes carried out through endless generations. It was Hugo de Vries who first brought evidence that some species at least may have a different origin. He was professor of botany in the University of Amsterdam and like Mendel carried on work of great importance in a garden of very small extent.

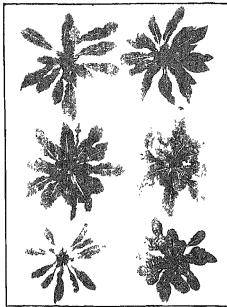
De Vries found the American evening primrose (Oenothera

biennis) growing in the outskirts of Amsterdam and noted that there were several distinct varieties of it. This variation in the plants appeared to him strange, for only a single species was listed and it seemed probable that all of the plants were descended from those that had escaped from cultivation and were originally of one kind. If this were the case the development of the new varieties had taken place since the introduction of the plant from America and had not required thousands or tens of thousands of years.



Journal of Heredity

Hugo de Vries. His merit was that he transferred the question of the origin of species from the realm of speculation to the field of experiment.



Journal of Heredity

Variations that De Vries discovered in the evening primrose. Two parent plants of the ordinary type are shown at the top. Below are four distinct mutants that appeared among the offspring.

De Vries planted seeds of the primrose in his garden and over a period of years raised many of the plants. He found, as he had suspected, that new forms appeared among them. He found also that these new forms came not through gradual changes, but all at once. Some of the seedlings were what breeders call "sports" — individuals distinctly different from The illusthe parents. tration shows some of the new types of plants that appeared.

De Vries found also that these changes in the primroses were

inherited and he advanced the idea that some species, at least, originate not by slow and very slight changes, but by distinct steps or leaps. Instead of the movement away from the parent stock being constant and so gradual that it is imperceptible, it is by a series of leaps with no movement between the leaps. This theory of the origin of species is called the *mutation theory* (Latin *mutare*, to change), or the *saltatory theory* (Latin *saltatorius*, pertaining to dancing).

Undoubtedly some new forms are established in this sudden way. Plant and animal breeders know many instances of new characters appearing all at once. Polled (hornless) breeds of cattle have been built up by preserving for breeding stock calves that were born without horns. In improving the speed of horses, the egg yield of hens, or the milk and butter record of dairy cows,

progress seems to come largely from finding decidedly superior individuals who are able to transmit their qualities. Such an individual — one that markedly excels its parents and relatives — is as truly a mutation or sport as is one very different in some visible physical quality. The outstanding families and strains found in all breeds of domestic animals are descendants of individuals of marked superiority.

It is the great merit of Hugo de Vries that he took the question of the origin of species out of the field of abstract discussion and brought it into the field of experiment. In the course of his work he discovered the lost experimental results reported by Mendel and directed attention to them. His earlier years were spent in fruitful researches in plant physiology, and biology was notably advanced by the contributions that he made.

FRANCIS GALTON

Francis Galton (1822-1911) was an English scientist of marked ability and wide interests. In his youth he engaged in explora-

tions in South Africa when much of that region was still unknown territory. He worked as a meteorologist and originated weather maps such as we use today. He was interested in finger-prints and worked out the system of classification still employed. He became interested in anthropology and achieved lasting fame

Brown Brothers

Francis Galton, the founder of eugenics. He performed a notable service by directing attention to the obvious fact that the laws of heredity apply to man.

through his studies on human heredity. His service to biology was twofold. He extended the applications of biology until it covered the field of human inheritance and he introduced the statistical method in the investigation of biological problems. The law of normal variation discussed on page 37 was discovered by the use of the statistical method and the quotation on that page is from Galton.

There are those who believe that if one has a good environment his ancestry is not important. Galton in his studies of human heredity did not find this to be the case. He found that in man as in other animals inheritance is vastly important. He showed in his study of British men of genius that the chances of a child of distinguished parents becoming distinguished were 19 times as great as were the chances of a child of undistinguished parents. Up to the time of Galton, biology had not given attention to the importance of good human stock. Galton brought this matter into scientific prominence. He originated the word eugenics, which in Greek means "well born." He believed that children inherit the abilities and character traits of their ancestors as they inherit their physical characters. In considering the workings of the laws of heredity Galton saw no reason for making an exception of man.

Galton is regarded as the Founder of Eugenics. His investigations and ideas gave birth to the eugenics movement, the believers in which hold that every child that comes into the world is entitled to parents who can give it a good heritage and a wholesome environment. His studies in human heredity have been followed by many others which confirm Galton's original conclusion that in man, as in other organisms, like tends to produce like. As yet we have made only a mere beginning in applying the knowledge thus revealed, but the time when eugenic measures will receive full consideration will surely come. From the exercise on page 702 you will realize that in a relatively short time a country can quietly change the character of its citizenry through the effects of a differential birth rate among different elements of the population.

EDWARD LEE THORNDIKE

The last builder of biology whom we shall mention is Edward Lee Thorndike, Professor of Educational Psychology in Teachers College, Columbia University. Although of our own time, he is a true biological pioneer. Most persons are willing to accept the findings of biology as they apply to lower organisms and to the physical qualities and needs of man. When they come to matters of human behavior and human relationships, they lay down their science and think as they please. Professor Thorndike has carried his science with him in his consideration of human affairs and has thus aided greatly in extending the territory in which scientific biological thinking is employed.

Early in his career and when little work had been done in that field, Professor Thorndike studied in a scientific way the learning processes of lower animals. By experimental methods he extended these studies to the field of human psychology and education and his "laws of learning" are accepted as valid guides in study and teaching. In addition to much other original work, he found time to take an active part in educational testing, by

which differences in intellectual abilities are measured. He has also devoted much time to the study of human interests as they are made evident by the way people spend their time and money. Most important of all, he



Edward Lee Thorndike, a biological pioneer of our own day. He has been a leader in winning for scientific biological thinking the territory which includes the nature and conduct of man.

Photo by Bachrach

has been a leader in the analysis of the original nature and the conduct of man.

In his social thinking Professor Thorndike accepts the idea that man has an inherited and complex instinctive equipment and that in arranging human relationships this must be taken into account. He has compiled a list of what he believes to be instinctive tendencies of man and indicated the conduct which in his judgment results from these tendencies. He has led the way in that new and much needed extension of human biology that includes not only the psychology of man but also his instinctive nature and that must serve as a guide in interpreting human nature and in the arranging of human social and political affairs. Professor Thorndike believes that we should not continue to run our complex educational and social systems without exact knowledge and in the hit-or-miss way we are now operating them. urges further research until we can deal with human beings and human problems in a scientific way. His book, Human Nature and the Social Order, is of very great value both for the information it contains and for its point of view.

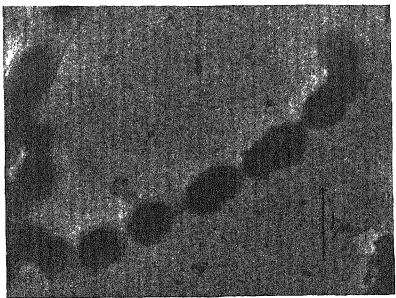
History gives perspective. No one understands a subject like one who is familiar with its origin and development. Your education and your understanding of biology will be widened by reading some of the many books that tell of the lives of great biologists and of the discoveries they have made.

PROBLEM TWO

What Recent Discoveries Promise Great Advances in Biology?

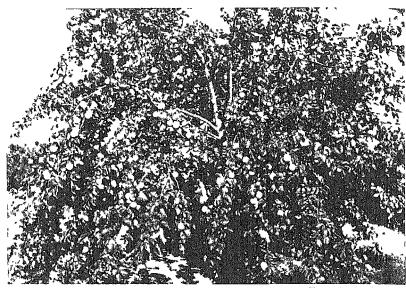
Biology advances as chemistry and physics advance and provide new methods for the investigation of biological problems. Two developments in these fundamental sciences that promise further rapid progress in certain fields of biology will be mentioned.

A new kind of microscope has been invented. It is an electron microscope; electrons instead of light rays are focused by it. The older microscopes gave magnifications up to 1000 to 2000 diameters. The electron microscope magnifies up to 100,000 and perhaps 200,000 diameters. It will reveal a world hitherto unknown to us. The illustration shows a photograph made by means of this remarkable instrument.



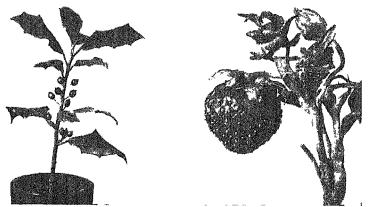
R. C. A. Bloctronic Research Laboratories

Streptococcus magnified 20,000 diameters by the electron microscope, an instrument which will open for us a new world.



 $American\ Chemical\ Paint\ Company$

Fruits and leaves fall because their stems are cut in two by a layer of corky cells that develops across them. Chemicals have now been found that prevent the development of this layer. The photograph shows a branch of an apple tree that was sprayed by such a chemical. It is loaded with fruit while the apples on the unsprayed part of the tree have dropped off.



F E Gardner and Paul C Marth, U S Dept Agriculture

Holly berries and a strawberry that developed without pollination of the flowers. The fruits were caused to develop by spraying the flowers with a chemical (naphthaleneacetic acid). Seedless tomatoes and seedless watermelons are now produced in this way. Great advances in biology are coming also from chemistry. We have referred to the effects of hormones, colchicine, and substances that promote root growth. Compounds that produce cancer are now known, and when we know the cause of cancer we shall probably know its cure. The accompanying photographs show the biological effects of other substances. Now a new method of attacking biological problems through chemistry has been developed.

You have heard of "heavy hydrogen" — hydrogen whose atoms have twice the ordinary weight. Perhaps, too, you have read of the way substances like potassium can be made artificially radioactive by bombarding them with neutrons from the great cyclotrons that physicists now have in their laboratories. By feeding substances that contain these heavy and radioactive atoms to animals, it is possible to trace the changes that the substances undergo within the animal body. The "tagged atoms" can be recognized and their courses traced through the cells. A far fuller understanding of the chemistry of living things promises to come from the use of this method.

Possibly in the near future chemical substances may be found that will relieve fatigue, make sleep unnecessary, and cure all germ diseases. Perhaps before long a person will be able to choose the height to which he will grow. There is nothing impossible in the idea that the problems of insanity, feeble-mindedness, and criminality will be solved through the chemical regulation of the body processes. Modern biology is only 100 years old and is yet in its infancy. What the discoveries of the next years will be no one can know.

PROBLEM THREE

What Are Some Important Applications of Biology in the Administration of Our Public Domain?

"The outdoors should be regarded as the source of pleasure and health and moral well-being for the people, and the wild things should be regarded as part of it."

DONALD HOUGH

The United States, exclusive of Alaska, has an area of about 600 million square miles. It belongs to us and we can use it as we wish. It includes mountains and deserts, lakes and swamps, broad tracts of fertile land. Most of it is controlled and used through private ownership. A part is retained for public use. The administration of this public domain is in the main a biological undertaking. It includes the care of our national forests and public grazing lands, wild-life conservation and preservation, the overseeing of the coastal fisheries and inland water resources. As the accompanying illustrations will suggest, one of the chief objectives in this work is to make possible a contact between the people and the outdoors.

One reason for placing the management of the wilder parts of our country in public hands is that in nature one change brings others. When two beavers made a dam on a small stream, the locality was completely changed. The trees that grew in the flooded area were killed. The squirrels that fed on their acorns and nuts were dispossessed. On the other hand, other kinds of plants and animals were benefited. Alders and other bushes moved in and grew around the margins of the water. The bushes supplied food for deer. Fish and crayfish found homes in the waters of the pond. Even the woodpeckers were benefited, for the dead trees provided them with convenient nesting places. When so great changes can follow the activities of two small animals, is it any wonder that man's operations in the field of nature need to be controlled? We must use care in the handling of our uncultivated areas or their value to us will be destroyed.



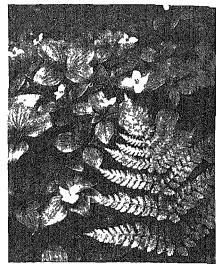
Outdoors in Fairy Stone State Park, Virginia.



Virginia Conservation Commissio

Lunch time in the Westmoreland State Park, Virginia.

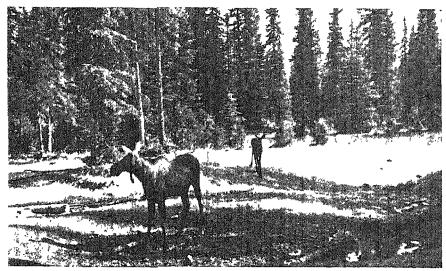




Bluebells in Grand Teton National Park and Canadian dogwood in Île Royale Park.



Azaleas in Smoky Mountain Park.

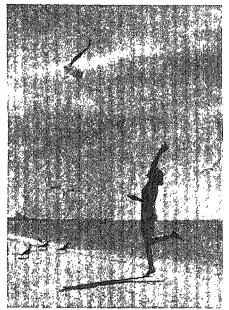


Moose in the north woods.

James Sauders

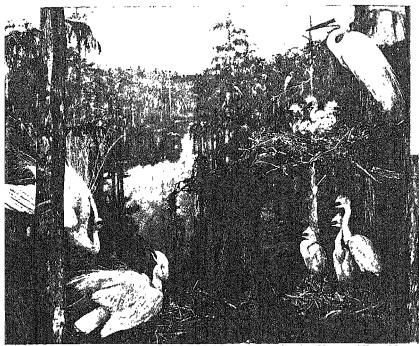


U. S Dept Intersor



James Sawders

Whistling marmot in Glacier National Park, and gulls on a Florida beach.



American Museum of Natural History

Egrets in Florida. They are one of the forms of wild life that have been sayed from extinction through protection given them by the government.



Ewing Galloway

Waterfowl in a public sanctuary on Chincoteague Island, Virginia. The wild things are the most interesting part of the outdoors and their care is an important part of administering the public domain.

PROBLEM FOUR

What Are Some of the Important Instinctive Social Traits of Man?

"There is an observed order of facts in respect to man which can neither be violated nor neglected with impunity." ARGYLL

Man is a product of both his original nature and of his training and it is difficult to determine what his actions would be if he followed his natural impulses alone. Yet the customs he adopts, the obligations he accepts, and the institutions he establishes reveal much concerning his instinctive social nature. Man tends to live by families, but he wishes to maintain his individuality within the family. The families usually gather in larger groups, but the family does not lose its identity in the group. It is evident that the human being is partly an individualistic and partly a socialized animal. In this brief study we shall consider a few human traits and the effects of these traits as they show themselves in general human society. Family relationships will not be taken into account here.

Individual social relationships. Human individuals are competitive and, in consequence, within the human group there is always a striving for place and power. There is a distinct tendency to the formation of castes, with individuals considering themselves superior in rank to some individuals and inferior to others. There are aggressive, dominating individuals and others (often of superior intelligence) who without much struggle accept less important positions.

In general it may be said that the human animal is selfish (individualistic) and tries to get and keep for himself. He lacks the complete community instincts of the bee and wants his own private possessions. Yet he has strong group instincts. He wants friends and companions upon whom he can rely in time of need and if he is a worthy individual he is willing to aid generously those whom he recognizes as having a right to call on him. He

wishes also to be a member of a larger organized group and he greatly desires a group leader who can be followed with confidence. It is said that the number of Eskimo bands depends on the number of leaders available. If a young man with the capacity and desire to lead arises, a number of families follow him and form a new band. If a group loses its leader and has no successor to take his place, it merges with another group.

Loyalty of individual to group. An individual usually has a loyalty to the group or the community to which he belongs. The sailor is for his own battleship, the soldier for his regiment, the student for his football team, and the citizen for the country in which he resides or for the race to which he belongs. There are many individuals whose loyalty to the general welfare of the group is very strong and who unselfishly strive for group welfare rather than for their own individual gain.

In other individuals, however, group loyalty is weaker than the desire for personal gain, and within a human group single individuals and bands of individuals (robbers, bandits, racketeers) may prey on their fellows. Many, too, are willing to live as parasites on the labors of others if they can do so. Group loyalties and individualistic instincts frequently conflict, and too often under these conditions personal advantage prevails over group welfare. Some human individuals are predatory within their own group to an extreme degree. Often it is difficult to determine whether group loyalty is real or whether the motive is the desire for individual advantage which will follow group triumph. Man leads both an individual and a group existence and the motives for human acts are often obscure.

Relations between human groups. There is a natural and instinctive competition between human groups and frequently this is accompanied by feelings of hostility. Sometimes football teams of neighboring schools cannot play each other because the enmity between the schools is so great. This rivalry is, of course, based purely on instinct, for intellectually it makes not the slightest difference who carries a ball over a white line. One primary cause of war is the urge on the part of one people to

show their power to subjugate another. Possibly there have been times and conditions when raids on a neighbor might bring a temporary gain of property and part of the support for war might have been a hope for individual gain. Now wars are so destructive that no one can hope to gain from them. The intellect condemns modern war as the most stupid folly of mankind, yet wars were never more prevalent. One military commander has said that "war is the highest experience of the race," but we can only believe that aggressive and unprovoked war is a bestial pack urge, representing the lowest and not the highest qualities of a race. It is strictly a product of the old primitive lower brain and not of the cerebrum.

It is possible for groups of human beings to live in friendly relation to each other and to confine their rivalry to those spheres where high attainments bring greater welfare to all. It is possible for them to become aligned in hostile array against each other and to compete in destructiveness. It is well to take account of the danger inherent in the human instinct for group competition and to understand the necessity of directing it in right ways and keeping it under control. Man is the only vertebrate that makes war on its own kind.

A fundamental trait. One trait of human nature that is almost universal is the desire for power over others. We are constantly reminded that "eternal vigilance is the price of liberty." Liberty is merely freedom from the grasp of other men, and men must struggle to keep free only because other men are always scheming and planning to get power over them. There is no such struggle in a prairie-dog town because prairie dogs do not try to conquer their fellow prairie dogs and hold them in subjection. There is such a struggle in a dog pack or in a chimpanzee band because in these animals there is a desire to rule.

Moreover, when human beings acquire unrestricted power . there is grave danger that the power will be unfairly used. The whole history of mankind in general is that when they have power to do as they please without restraint they are unjust and often tyrannical for the mere pleasure of showing their power. Indi-

viduals and peoples alike are in a precarious situation when their welfare is in any hands but their own. One statesman said that he had never seen a man whom he would trust to take care of him. It is not safe to grant authority to anyone unless the power to withdraw it is retained.

Human society necessarily imperfect. Man is too individualistic in his nature to be a perfect citizen within his group. Whatever way we look at it, human character is defective from a social point of view. It follows that our social institutions and political organizations must show defects. Medical service is not so good as it should be because doctors are not so good as they should be. There are abuses in the law because lawyers are bound to show the character defects that man has. If we pass laws for the regulation of society, there will surely be corruption and neglect of duty among the regulators. When we examine the workings of social institutions (churches, schools, coöperative societies), always there are defects. If we look into industrial and economic relationships and organizations, we find that they are never perfect. Set up any type of government you wish and always you will find in its workings inefficiency and often corruption and tyranny.

"The most usual error in social and political thinking is to ascribe the evils that are due to the defects of human nature to the institution or system in operation at a particular time and place." Often it is thought that if a system or organization were changed the difficulty would be got rid of, whereas the same people of the same type would take charge of the new system and the difficulties would remain. Always in any system the final decisions are made by imperfect men, and the administration is in the hands of such men. It is easy to set up a theoretical Utopian scheme for perfect people, but it is indeed hard to lay out a plan that will work with people as they are. In trying to improve their systems, people often change to something that is worse than they already have.

Morality of the human group. Men act not only as individuals but as groups, and in general group morality in human

society is far below individual morality. It follows that to say of a government or a measure that it is democratic is not to say that it is wise or just. Democratic (Greek demos, people) means "according to the will of the people," and a majority of the people, as members of a class or a group, are perfectly capable of committing the grossest injustices. No one is safe in a society or a government where there is not some way of protecting an individual or a minority from the unjust actions of a majority. There is nothing more democratic than a mob hanging an innocent victim who, if given an opportunity, might be able to prove that he had not been within miles of the scene of the crime.

A machine that violates the laws of nature is a bad mechanical contrivance and will surely crash. Likewise a legislative act or a social or political order that is antagonistic to the innate being of man can bring only disaster in its wake. We must take into account the facts (laws) of human nature when arranging the affairs of man. Law reigns and the first requisite for intelligent living under it is a knowledge of it.

PROBLEM FIVE

Is the Constitution of the United States a Sound Biological Document?

Our nation was founded by a set of free men who met and without compulsion from any source laid out the scheme of government that to them seemed best. Get a copy of the Constitution which they framed and read it as you make this study. Government is strictly a biological undertaking and you are asked to judge whether the founders of our government in their judgment of human nature were good biologists.

Purposes of the founders. The purposes of the men who planned our government were clear. They wished to establish a central government strong enough to preserve internal order, to provide for defense against external foes, and in general to do those necessary things that the separate states could not do for themselves. At the same time, they wished to arrange matters so that the central government they were establishing could not use its powers to oppress the citizen. The Declaration of Independence and Adam Smith's Wealth of Nations had been issued only eleven years before and naturally the Founding Fathers were influenced by the ideas of the times. They assumed without discussion that it is desirable for men to be free and that a free competitive economic life is best. They accepted also the idea that man seeks power over his fellow man, and from their experience and knowledge of history they knew that unrestricted power when it is acquired is almost universally abused. They did not trust majorities of the people, if given power, to be just to minorities any more than they trusted individuals. They accepted the evident fact that man, because of his selfishness and his desire to rule over others, is a defective social creature. The men in the Convention were not academic theorists, but practical, experienced men like George Washington and Benjamin Franklin, and they sat down to lay out a plan of government that would fit man as he is and not as he ought to be.

Protection against governmental tyranny. It was the provisions for protecting the citizen from government oppression that formed the distinctive feature of the American plan. It was a newer and greater thing in government than is generally understood. To carry out their purposes, the founders of our government drafted a written Constitution in which their plan of government was outlined. Here are some of the provisions made to guard against tyranny by the central government:

State governments were to be maintained to look after local affairs. The new central government was to have authority only in general matters of interest to the whole country. In regard to the state governments the central government guaranteed only that they should be of republican form.

The central government was given only the powers considered necessary for it to carry out the duties assigned to it. All powers not given to it were expressly reserved to the states or to the people. The central government could do nothing the Constitution did not authorize it to do.

All officers of the government were to be elected by the people or to be appointed by elected officers. The people were to choose their own rulers, and most of these served for only limited terms. Thus, the final power behind the government rested in the hands of the people themselves. There were to be no hereditary governing classes.

The national government was to be divided into three independent branches — legislative, executive, and judicial. The purpose of the division was to keep any one individual or branch of the government from gaining too much power. The Congress was to make the laws and it could make none the Constitution did not authorize it to make. The President was to enforce the laws and he could not enforce any measures Congress had not approved and passed. The judges held the power to decide whether the authority of Congress or of the President was being exceeded. The Supreme Court judges were appointed for life, so that they would be independent and could make their decisions without fear of Congress or the President.

Protection against majorities. The Founding Fathers tried also to provide against a tyranny of a majority of the people. They therefore set up a republic; the government was to be carried on by representatives of the people and not directly by the people themselves. The founders knew that temporary majorities of a people are likely to go wrong and that a permanent majority might obtain possession of the government and oppress a minority. They tried to provide against this possible danger from the people in several ways.

The first of these ways was by having the President elected not directly by the people but by a set of electors chosen from each of the states. It is well known that the man who can go out and captivate the crowd and get the votes is often not a wise and safe leader; so it was provided that the President should be chosen by a small body of men who would not be so likely to be influenced by eloquence and here worship.

A second provision against unwise action was to have a higher branch of Congress (the Senate) to pass on and check the actions of a lower branch (the House of Representatives). Provision was made, also, for the election of Senators by state legislatures instead of by popular vote and for them to serve for terms of six years. It was thought that a more intellectual type of man would be chosen in this way than by popular election and that the members of the Senate would be freer from the influence of pressure groups. This would help to prevent hasty and too radical legislation from being passed.

The Bill of Rights. A definite check on the use of arbitrary power is in the Bill of Rights, which was adopted in ten Amendments immediately after the Constitution was adopted and is really a part of the original Constitution. In order to make it unmistakably clear that the government has no authority to take away certain rights from the citizen, it was specifically stated in the Bill of Rights that Congress shall pass no laws interfering with various rights and liberties.

Among the rights guaranteed by the Bill of Rights are freedom of speech, freedom of the press, freedom of religion, and the right to assemble peaceably and petition the government for redress of grievances. The right to keep and bear arms and the right of trial by jury if a citizen is accused of a crime are not to be taken away from him. The citizen's property is not to be taken for public use without just compensation. Read the Bill of Rights for yourself. The people who founded our government were afraid to clothe men with official power unless it was clearly set down in written form exactly what they were allowed to do and what they were forbidden to do. They realized that the great oppressor of mankind is the organized state; that there is no tyrant to be feared like the one who has the authority of government at his command.

Thomas Jefferson said that we should have "a frugal and just government that will prevent men from injuring each other and will not take from the mouth of labor the bread it has earned." He thought and many others still think it wisest that the government should be limited to a very narrow field, its chief internal duty being to prevent crime and to oversee only those affairs that private citizens cannot attend to for themselves. The United States government as it was originally laid out was a government of this kind. One difficulty with an extended government is that it is exceedingly difficult to administer it without giving to the administering officials powers that may be oppressive and that cannot be strictly limited and defined.

The founders of our government had had experience with an arbitrary government operated from a distance. Unlike some of those who have always lived in freedom and security, they understood the value of liberty and prized it above all things. They tried to provide first of all that the government should not become an oppressor of the people. Of the success of their efforts and of the wisdom of the changes we have made in our government since its establishment, we leave you to judge. The purpose of the problem is to set you to studying political and social matters in biological terms. In biology we study the ways of bees and beavers. Why not the ways of men?

CONCLUDING THOUGHTS

"The future progress of the world depends on whether man uses the old jungle method of thinking or whether he will make his thinking scientific."

R. A. MILLIKAN

"At present man's politics are largely a matter of prejudice; but the effects of his legislation are rigorously determined by biological laws. The sooner these laws are understood, and the sooner reason takes the room of prejudice, the better for the human race."

S. A. McDowall

"He that voluntarily continues ignorance is guilty of all the crimes which ignorance produces."

SAMUEL JOHNSON

"Education is the instruction of the intellect in the laws of nature, under which name I include not merely things and their forces, but men and their ways; and the fashioning of the affections and of the will into an earnest and loving desire to move in harmony with those laws."

THOMAS HENRY HUXLEY

"I am led to reflect how much more delightful to an undebauched mind is the task of making improvements on the earth than all the vainglory which can be acquired from ravaging it by the most uninterrupted career of conquests."

George Washington





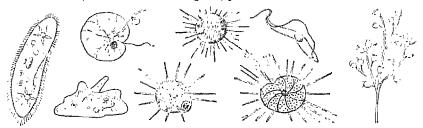
APPENDIX A

Classification of Animal and Plant Kingdoms

The outline which follows is intended to give only a very general view of the main animal and plant groups. The page citations are to more detailed discussions of the groups.

ANIMAL PHYLA

I. PHYLUM PROTOZOA (prō'to-zō'a); Greek protos, first, + zoou, animal; first animals. Singular, protozoon.



Noctiluca

Ameba

Radiolaria Trypanosoma

Paramecium

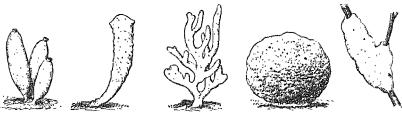
Heliozoa

Foraminifera

Carchesium

A great and very diverse group of microscopic one-celled animals. Found in the soil, in fresh waters, and in the sea. Many of them are parasites in larger organisms and the members of one class (Sporozoa) are all parasites. Protozoa are a principal cause of disease in mammals and birds. Examples are: paramecium, ameba, malaria germ (pages 272-280, 589, 859).

II. PHYLUM PORIFERA (po-ríf'er-a); Latin porus, a pore, a small opening, + ferre, to bear; pore bearers. The sponges.



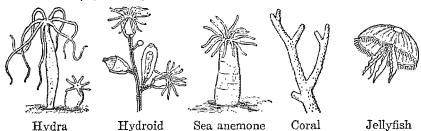
Grantia Venus's flowerbasket.

Finger sponge

Bath sponge

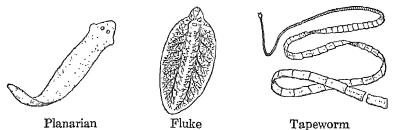
Spongilla

Simple stationary animals of both fresh and salt water. They get their food from small particles in the water which passes through the canals and openings of the body (page 288). III. PHYLUM COELENTERATA (se-lĕn'ter-ā'ta); Greek koilos, hollow, + enteron, an intestine. The coelenterates.



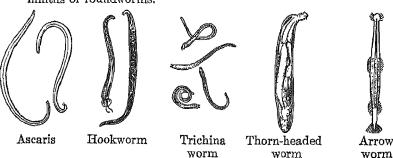
Animals with simple hollow bodies and tentacles about the mouth. Most of the coelenterates live in the sea. Examples are: hydras (page 301), jellyfishes, sea anemones, corals (pages 801-804).

IV. PHYLUM PLATYHELMINTHES (plāt/i-hēl-min'thēz); Greek platys, flat, + helmins, worm; flatworms. The platyhelminths or flatworms.



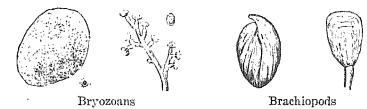
The flatworms are simple in body and most of them are small. The body has a head end with a rudimentary brain. Many are parasites. Examples are: planarians (page 314), tapeworms, flukes (page 571).

V. PHYLUM NEMATHELMINTHES (něm'a-thěl-min'thēz); Greek nema, thread, + helmins, worm; threadworm. Nemathelminths or roundworms.



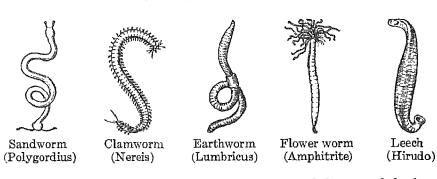
White, unjointed worms, usually small. They are abundant in the soil and many are parasites in the roots of plants and in animals. Examples are: trichina, hookworm, and many other worms parasitic in the intestines of higher animals (page 317). The arrow worms are free-swimming forms that live in the sea (page 833), and except in their general form they have little resemblance to the other members of the phylum.

VI. PHYLUM MOLLUSCOIDEA (mol'us-koi'de-a). The name is derived from the fact that some members of the phylum have mollusk-like shells.



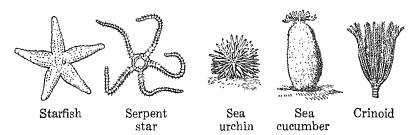
The phylum is made up of two groups—the Bryozoa (Greek bryon, moss, + zoon, animal; a moss animal) and the Brachiopoda (Latin brechium, arm, + Greek pous, foot; arm-footed). Each is a very ancient group that still survives. The Bryozoa are mostly marine and the brachiopods entirely so (pages 834, 835).

VII. PHYLUM ANNELIDA (a-něl'ī-da); Latin anellus, a small ring. Annelid (ăn'e-līd), or segmented worms.



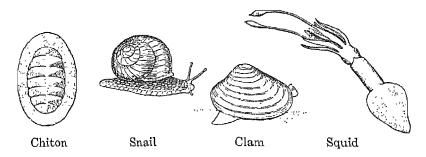
An annelid has a head, brain, and a nerve cord that extends back through the body. The body is divided into joints or segments. The members of the various classes of the phylum differ greatly from each other. Examples are: earthworm (page 322), leech, sandworm, flower worm (pages 832, 852).

VIII. PHYLUM ECHINODERMATA (e-ki'no-dur'ma-ta); Greek echinos, spiny, + derma, skin; rough skin. The echinoderms.



A group of sea forms very different from any animals of fresh water or of the land. As in the coelenterates, the echinoderm body is built about the mouth and there is no head end. Examples are: starfishes, sea urchins, sea cucumbers, crinoids (page 805).

IX. PHYLUM MOLLUSCA (mŏ-lŭs'ka); Latin mollis, soft. The mollusks.

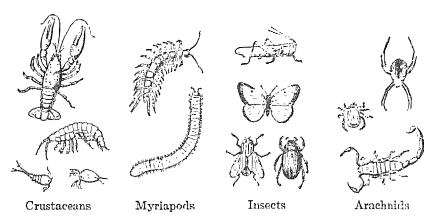


Soft-bodied animals, most of them with the body enclosed in a shell. A great group found in both fresh and salt water and to some degree on the land.

- 1. Class Lamellibranchiata (la-měl'ĭ-brăng'kĭ-ā'ta); Latin lamella, a small, thin plate, + Greek branchion, a gill; with flat gills. The lamellibranchs, or bivalve mollusks. Examples are: oyster, clam, mussel, scallop, shipworm (page 812).
- CLASS GASTROPODA (găs-trŏp'o-da); Greek gaster, stomach, + pous, foot; stomach-footed. The gastropods.
 Twisted shell in one part. Some without shell. Examples are: snails, slugs (page 815).
- 3. Class Cephalopoda (sĕf'a-lŏp'o-da); Greek kephale, head, + pous, foot; head-footed. The cephalopods.

Most of the cephalopods have the remains of a shell buried within the back. They have long grasping tentacles about the mouth and swim by shooting out a jet of water. Examples are: octopus, squid, chambered nautilus (page 819).

X. PHYLUM ARTHROPODA (ar-throp'o-da); Greek arthron, joint, + pous, foot; jointed limb. The arthropods.



The arthropods have jointed limbs and a hard covering over the outside of the body (exoskeleton), to which the muscles are attached on the inside. They have a brain, nerve cord, and usually compound eyes. Abundant both in the water and on the land (page 328).

- 1. Class Crustacea (krus-tā'she-a); Latin crusta, crust. Often have limy covering of the body. A crustacean has gills and practically all crustaceans live in the water. Examples are: crayfish, crab, lobster, and many smaller forms (page 825).
- 2. Class Insecta (in-sek'ta); Latin insectus, cut in, divided.

 The insects get their name from the fact that the insect body is divided into three parts. They have six legs and tubes through the body for breathing air. There are many orders in the class and more than 400,000 species have been named. Examples are: flies, mosquitoes, beetles, butterflies, ants, dragonflies (page 332).
- CLASS ARACHNIDA (a-răk'nĭ-da); Greek arachnes, spider. The arachnids.

The arachnids have eight legs. The body is in two parts. Examples are: spiders, scorpions, ticks, mites (page 354).

XI. PHYLUM CHORDATA (kor-dā'ta); Greek chorda, a cord. The chordates.

The chordates have either a rod of fibrous material called a *noto-chord* or a chain of bones down the back of the body. In them the nerve cord is in the back of the body instead of down the ventral side as in the annelid worms and arthropods.

- (A) Subphylum Enteropneusta (ĕn'ter-ŏp-nūs'ta).
- (B) Subphylum Tunicata (tū'nĭ-kā'ta).
- (C) Subphylum Cephalocorda (sĕf'a-lo-kor'da).

 The above three subphyla include a number of kinds of little sea animals that have notochords but not backbones (page 836).
- (D) Subphylum Vertebrata (vur'te-brā'ta); Latin vertebratus, jointed. The vertebrates.

The vertebrates have jointed backbones and jointed skeletons buried within the body. They are by far the largest of all animals and are abundant both in the water and on the land. The jointed backbone makes the body flexible and enables the animal to turn easily. The vertebrates are arranged in seven classes.

- CLASS CYCLOSTOMATA (sī'klo-stō'ma-ta); Greek kyklos, ring, circle, + stoma, mouth. The cyclostomes.
 Cyclostomes have round sucking mouths with no jaws. No side fins. Skin smooth and slimy. Examples are: lamprey eels, hagfishes (page 837).
- 2. Class Elasmobranchii (e-lăs'mo-brăng'kĭ-ī); Greek elasmos, a metal plate, + branchion, a gill; with plate-like gills. The elasmobranchs.

The skeleton of an elasmobranch is made of cartilage. There are no gill covers. Examples are: sharks, rays (skates), chimeras (page 838).

- 3. Class Pisces (pis'ēz); Latin *piscis*, fish. The fishes. Includes the many kinds of fishes with bony skeletons (page 378).
- 4. Class Amphibia (ăm-fîb'î-a); Greek amphi, both, + bios, life; both lives i.e., on land and in water. The amphibians.

Have gills in the early (tadpole) stage and develop lungs in the adult form. The class includes the salamanders, frogs, toads (page 385). CLASS REPTILIA (rep-til'i-a); Latin reptilie, creeping. The reptiles.

Dry scaly skins. Breathe by lungs. The large eggs have membranous coverings and are laid on land. The members of the class are the crocodiles, lizards, turtles, and snakes (page 389).

- 6. Class Aves (ā'vēz); Latin aris, bird. Birds. Birds are warm-blooded vertebrates with feathers and wings. Eggs with firm shells. Skin dry. There are many orders and there are forms adapted for life under many different conditions (page 407).
- Class Mammalia (mä-mä'li-a); Latin mamma, breast. The mammals.

Mammals are warm-blooded animals that have hair and feed their young on milk. The most recent and highly developed of all the animal groups.

- a. Subclass Protoiheria (prō'tō-thē'rī-a). Egg-laying mammals.
 - Only three living species, the duckbill and the spiny anteaters of Australia (page 422).
- b, Subclass Entheria (yū-thē'rī-a). Mammals whose young are born alive.
 - (1) Marsupials. Young born in a very immature condition and reared in a pouch on the abdomen of the mother (page 426).
 - (2) Placental mammals. Young wrapped before birth in a covering called the placenta, through which it derives nourishment from the blood of the mother. Young born in a more or less advanced stage of development. The great group of modern mammals (page 437).
 - Order 1. Insectivora (in'sĕk-tiv'o-ra), Insect eaters, Shrews, moles, and hedgehogs (page 438).
 - Order 2. Dermoptera (der-mŏp'ter-a). Flying lemurs (page 95).
 - Order 3. Chiroptera (kī-röp'ter-a). Bats (page 439).
 - Order 4. Carnivora (kar-niv'o-ra). Flesh-eating land mammals and seals (page 443).
 - Order 5. Rodentia (ro-dĕn'shĭ-a). Gnawing mammals, Mice, rabbits, squirrels, beaver (page 440).

- Order 6. Edentata (ē'dĕn-tā'ta). Toothless mammals.

 American anteater, sloth, armadillo (page 441).
- Order 7. Pholidota (fòl'i-dō'ta). Pangolin or scaly anteater (page 202).
- Order 8. Tubulidentata (tū'bu-lǐ-dĕn-tā'ta). Aardvark (page 441).
- Order 9. Primates (pri-mū'tēz). Lemurs, monkeys, apes, man (page 444).
- Order 19. Artiodactyla (ar'tĭ-o-däk'tĭ-la). Even-toed hoofed mammals. Hogs, hippopotamus, deer, cow (page 448).
- Order 11. Perissodactyla (pe-rĭs'o-dăk'tĭ-la). Odd-toed hoofed mammals. Horse, tapir, rhinoceros (page 447).
- Order 12. Proboscidea (prō'bo-sĭd'e-a). Elephants (page 451).
- Order 13. Sirenia (sī-rē'nĭ-a). Sea cows (page 450).
- Order 14. Hyracoidea (hī'ra-koi'de-a). Rodent-like hoofed mammals. Coneys (page 449).
- Order 15. Cetacea (se-tā'she-a). Whales and dolphins (page 452).

Note. In addition to the animal phyla in the foregoing list there are two others, Ctenophora (te-nof'o-ra) and Rotifera. The Ctenophora include small sea animals called sea combs and sea walnuts. The rotifers are described on page 835.

PLANT PHYLA

I. PHYLUM THALLOPHYTA (thă-lòf'i-ta); Greek thallos, tender young shoot, + phyton, plant.



Álgae Fungi

Plants with soft bodies. Thallophytes have no wood or other hard tissues.

1. CLASS ALGAE (ăl'jē); Latin alya, seaweed. Singular, alga (ăl'ga). The algae.

Small plants with green coloring matter. Mainly water plants. Very important as food for water animals. The four main divisions are:

a. Blue-green algae.

Very small and simple forms that have a bluish pigment in addition to chlorophyll (page 227).

b. Green algae.

Bright green in color. Mainly a fresh-water group. The pond scums and the green growths on rocks and sticks in slow streams are green algae. Larger and more highly developed than the blue-greens (page 230).

c. Brown algae.

A group of seaweeds that have a brown pigment in addition to chlorophyll. Most abundant along temperate coasts. Includes the kelps and rockweeds (page 847).

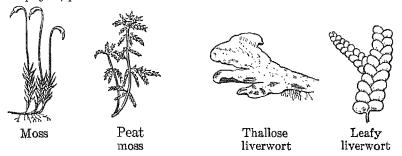
d. Red algae.

Red pigment in addition to chlorophyll. The larger ones are fine branching seaweeds. A few fresh-water forms. Most abundant in warmer seas (page 848).

 CLASS FUNGI (fŭn'jī); Latin fungus, a mushroom. Singular, fungus (fúng'gus). The fungi.

The fungi lack green color. Many kinds live on dead organic matter and many are parasitic on other plants. Examples are: molds, mildews, rusts, smuts, mushrooms, puffballs. Bacteria are often included with the fungi (pages 284, 293).

II. PHYLUM BRYOPHYTA (brī-ŏf'i-ta); Greek bryon, moss, + phyton, plant.



Small and simple plants. Nearly all bryophytes are land plants, but many of them grow only in moist or shady places.

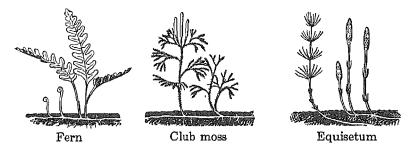
- 1. Class Musci (mus'sī); Latin muscus, moss. The mosses.

 Small plants. Erect or trailing; often in dense tufts or clumps.

 Spores are produced in capsules borne on stems that stand erect above the leafy plant. Examples are: sphagnum (bog moss) and common mosses of the roadsides and woods (page 873).
- 2. Class Hepaticae (he-păt'i-sē); Greek hepar, the liver. The liverworts.

Very small flat plants. The most common species grow on wet banks or wet rocks. In warm, moist climates some kinds are found on trees. A few species are small floating forms on the surface of lakes and pools (page 878).

III. PHYLUM PTERIDOPHYTA (těr'i-dŏf'ĭ-ta); Greek pteris, fern, + phyton, plant. The fern plants.

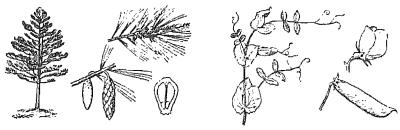


The most familiar pteridophytes are the ferns. In past geologic ages plants of this phylum were much more prominent than they are now.

- 1. Class Filicales (fil'I-kā'lēz); Latin filix, fern. The ferns. Plants whose long, feathery leaves (often called fronds) have given the name Pteridophyta to the phylum. Most ferns have short underground stems, but the stems of the tropical tree ferns grow erect (page 881).
- 2. Class Lycopodiales (lī'ko-pō'dĭ-ā'lēz); Greek lykos, wolf, + pous, foot. Lycopodiums or club mosses.
 - The class includes the evergreen plants that in the Northern states are called ground pine and in the Southern states running cypress and running cedar. The stems are trailing and the leaves are small (page 153).
- 3. Class Equisetales (ĕk'wĭ-se-tā'lēz); Latin equus, horse, + seta, stiff hair, bristle. The horsetails.

Leafless plants that grow in dry places and are sometimes called scouring rushes. They get the name "horsetail" from their shape (page 154).

IV. PHYLUM SPERMATOPHYTA (spur'ma-tof'i-ta); Greek sperma, seed, + phyton, plant. The seed plants. The two great classes of spermatophytes are the gymnosperms and the angiosperms.



Gymnosperm

Angiosperm

- CLASS GYMNOSPERMAE (jim'no-spur'mē); Greek gymnos, naked, + spcrma, seed; naked seeds. The gymnosperms.
 - Seeds not enclosed in a seed pod or fruit; usually produced in cones. The tropical and subtropical cycads, which resemble palm trees, are gymnosperms, as are the pines, firs, cedars, hemlock, cypress, and other evergreens. Practically all gymnosperms are trees (page 887).
- 2. Class Angiospermae (ăn'jĭ-o-spur'mē); Greek angeion, a vessel, capsule, + sperma, seed; seeds hidden or enclosed. The angiosperms.

Seeds are enclosed in an ovary or seed vessel. Many of the angiosperm group have showy flowers. Our broad-leafed trees and shrubs, the grasses, and all the herbs of our gardens, fields, and roadsides are angiosperms. The two great divisions of the angiosperms are the dicots (dicotyledons) and monocots (monocotyledons) (page 893).

NOTE. The grouping of the plant phyla given here does not take care of the bacteria and of some other small forms in a very satisfactory manner. You will find a discussion of these on pages 281–287.

APPENDIX B. Divisions of Geological Time

DOMINANT FORMS OF LIFE		, ,	Age of primitive invertebrates	Age of higher	invertebrates	Age of fishes			Age of amphibians	
ADVANCES IN LIFE	Birth and growth of the earth. Later stages marked by the formation of rocks. Early stages represent the unrecoverable beginnings of earth history. No evidence of life. Betimated length from 300 to 1200 million years.	Fossils unknown but beds of iron ore and graphite in the rocks lead to behef that unneellular plants and animals existed. Estimated length from 300 to 800 million years.	Oldest known fossils. Foraminifera, worms, and marine plants (algae). Estimated length from 600 to 750 million years.	Marine fossils for the first time abundant. Trilobites, brachiopods, and grapto-lites prominent. Earliest crustaceans. No remains of land plants, but it is thought that on the lowlands at least vegetation was present.	Seas widespread. Trilobites abundant and of many lands. A few small armored fishes (ostracoderms) appear. Rise of land plants and corals.	Climate warm. Widespread coral reefs. Cephalopods appear and small fishes are more abundant. Eurypterids abundant. Development of land plants.	Fishes dominate all life forms. 40 per cent of all were arthrodizans. Climax of brachiopods. Lungfishes develop into amphibia. First forests appear.	Great development of sharks. Crinoids, hryozoans reach climax. Rise of echinoderms.	Rise of primitive reptiles. Period of giant insects (called "Age of Cockroaches"). Great coal forests but no flowering plants. Many kinds of amphibia.	Rise of land vertebrates and modern insects. Beginning of warm blood. Trilobites almost gone.
EPOCHS										
Periods				Cambrian	Ordovician	Silurian	Devonian	Mississippian	Pennsylvanian	Perminn
Eras	Azorc	Акснвогогс	Protenozuic			Palbozoic	Estimated length, 340 million years			

Eras	Periods	Еросиѕ	ADVANCES IN LIPE	Porms of Life
	Triassic		Rise of dinosaurs and reptilian mammals.	Age of pteriolo-
Mesozoid Estimated length, 140	Jurassic		Dinosaurs and marine reptiles dominate. Toothed birds appear. Cycads cluef land plants.	Age of reptiles
million years	Cretaceous		Flowering plants and hardwood forests appear. Dinosaurs and toothed laids climax and then die out.	
		Равосепе	Archaic mammals dominate.	-
		Еосепе	Modern mammals arise. Archaic mammals die out.	,
CENOZOIC	Tertiary	Oligocene	Rise of higher manmals and modern birds. Apres appear in Euravia.	mammals Great
Estimated length, 60 million years		Miocene	Chinax of mammats. Many grazing types appear as grasses and cereds become abundant.	development of herba- recuts
		Pliocene	Appearance of man. Climate becomes reoder and drier.	
	Quaternary	Pleistocene	Stone Age of man. Glaciation widespread. Extinction of many large mammuls.	3.5
Modern Estimated length,		Recent or post- glacial	Rise of human civilization. Cupper, Bronze, and Iron Ages.	Лде об тап
20,000 years			The state of the s	



Below is a partial list of the biological terms commonly used. Only the biological meanings are given here. The meanings and pronunciations of many other terms may be found by consulting the index and the page references there given.

- aboral (ab-o'ral). Opposite to or away from the mouth.
- acquired characteristic. A characteristic which is the result of environment; not inherited (pages 697-698).
- adaptation. The modification of a structure or trait, which fits a plant or an animal to its environment or to its way of life.
- afferent (afferent). Carrying to or inward. Applied to nerves that convey impulses inward to the nerve centers. See page 493.
- albumin (ăl-bū'mĭn). A simple protein found in nearly every animal and in many plant tissues; dissolved by water and coagulated by heat.
- allergy (M'er-ji). Abnormal sensitivity to food, pollen, hair, or other substances ingested or inhaled.
- alternation of generations. The alternating of a sexual and an asexual generation in the life history of an organism. Each generation produces offspring different from itself, as in the hydroids and ferns. See pages 798–800, 883–885.
- amino (a-mē'no) acids. Organic acids containing the amino (NH₂) radical, and from which proteins are built (pages 619-620).
- amnion (ăm'nĭ-on). A membranous sac containing the fluid that encloses the embryo in mammals, birds, and reptiles.
- analogous (a-năl'o-gus). Similar in function but not corresponding in origin and structure, as the wings of insects, bats, and birds.
- annual. Occurring once a year. Also, a plant that completes its life cycle in a single year or season.
- antenna. One of a pair of jointed appendages or "feelers" on the head of an arthropod.
- antheridium (ăn'ther-id'I-um). The male sex organ in some of the flower-less plants (e.g., mosses, ferns). See pages 874-875.
- antibody (ăn'tĭ-bŏd'ī). Any substance formed in the body of an animal when foreign material is introduced. An antibody combats the ill effects of the foreign material. See page 598.
- antitoxins (ăn'tĭ-tŏk'sĭns). Antibodies that neutralize the poisons (toxins) given off by disease germs. Also, sera that contain antitoxins. See page 596.
- antivenin (ăn'tĭ-včn'ĭn). An antibody that neutralizes snake venom, or a serum containing antivenin.
- aquatic (a-kwat'ik). Pertaining to water. Also, living in or adapted to water.
- arboreal (ar-bō're-al). Pertaining to trees. Living in trees.

archegonium (ar'ke-gō'nĭ-um). The female sex organ of mosses and ferns. The archegonium contains the egg. See page 875.

- asexual (a-sek'shoo-al) reproduction. Any mode of reproduction in animals or plants that does not involve the union of two individuals or of reproductive cells.
- assimilation (a-sim'i-lā'shun). The process by which food is transformed into living tissue.
- attenuated (a-ten'u-at-ed). Weaker; less virulent (page 588).
- axon (ăk'sŏn). The principal elongated branch of a nerve cell. The axon forms the central core of a nerve fiber.
- balance of nature. A condition in nature in which the plants and animals of a region maintain relatively unchanging numbers.
- bilateral (bī-lăt'er-al) symmetry. Having two sides of the body alike.
- biogenetic (bī'o-je-nĕt'ĭk) law. The theory that a plant or an animal in its individual development repeats in a greatly shortened form the development of its race (pages 133-136).
- bisexual (bī-sĕk'shŏŏ-al). Having both male and female sex organs in the same organism.
- bond theory. The theory that the paths followed by nerve impulses (neural pathways) are determined by the touching or joining of the dendrites of certain neurons. The theory is that the impulse passes through the neurons whose dendrites are in contact with each other.
- carapace (kăr'a-pās). The hard protective case covering the dorsal surface of certain animals (e.g., crustaceans, turtles).
- carbohydrate (kar'bō-hī'drāt). Starches, sugars, cellulose, and similar compounds. Any compound made up of carbon in groups of six atoms and of hydrogen and oxygen in the proportion to form water.
- carnivorous (kar-niv'o-rus). Flesh-eating.
- catalyst (kăt'a-list). A substance that causes or hastens a chemical change without itself being changed.
- cell differentiation. Specialization of the cells for different kinds of work. Cell differentiation differs from ordinary growth (simple cell enlargement) in that the cells become unlike the parent cells. See pages 131–132.
- cellulose (sčľu-lōs). A carbohydrate with the same general formula as starch. Found in plants as the chief constituent of cell walls.
- cephalic (se-făl'ĭk). Pertaining to the head.
- cephalic index. The ratio of the width of the head to its length. The quotient obtained by dividing the width of the head by its length.
- cephalothorax (sĕf'a-lō-thō'rāks). The fused head and thorax of certain arthropods, as crustaceans and arachnids.
- chemiculture (kem'i-cul'ture). The growing of plants in water or sand cultures. Hydroponics.
- chitin (kī'tĭn). The tough, horny substance forming the exoskeleton of arthropods.

- chloroplasts (klō'ro-plāsts). Structures in the cytoplasm of the plant cell that manufacture and contain chlorophyll.
- chorion (kō'rĭ-ŏn). The outermost membrane surrounding the fetus or developing embryo of a placental mammal.
- chromatin (krō'ma-tin). A part of the cell nucleus which takes a deeper stain than the rest of the nuclear material. In the resting nucleus it appears as a tangle of fine threads and granules, and in mitosis is collected into chromosomes.
- chromosomes (krō'mo-sōms). Curved or rod-shaped bodies formed from the chromatin at the time of cell division.
- chrysalis (kris'a-lis). The resting stage or pupa of an insect.
- cilia (sĭl'ī-a; singular *cilium*). Vibrating, hair-like projections of protoplasm on the surface of a cell.
- cion (sī'un). A piece cut from a twig or a shoot for grafting into another plant. Also spelled *scion*.
- cloaca (klo-ā'ka). A cavity into which the intestine, kidneys, and reproductive organs discharge their products in most vertebrates except the higher mammals. The central cavity of a sponge.
- collar cells. Flagellated cells that have a collar of soft protoplasm around the base of the flagellum. Found in some of the protozoa (Monosiga, Condosiga, page 279) and in sponges.
- commensalism (ko-mčn'sal-ĭz'm). The living together of two organisms in which neither is injured and one or both are benefited.
- conditioned reflex. A learned or acquired reflex action; one that is not natural or inherited (page 728).
- conductivity. Ability to convey or conduct. Applied to protoplasm and especially to nerve tissues because of their ability to conduct an impulse to parts distant from the point where the impulse arises.
- conjugation (kŏn'jŏŏ-gā'shun). The union of equal gametes or sex cells. Distinguished from fertilization, in which the gametes are differentiated into egg and sperm. See pages 273-274.
- convergent development. The development of similar form and structure by unrelated organisms living under similar life conditions. Same as parallel development. See pages 95-96.
- corpus callosum (kôr'pŭs kā-lō'sŭm). A mass of white matter made up of transverse fibers connecting the two hemispheres of the cerebrum.
- cortex. The outer layer of certain plant and animal organs such as the stem, root, brain, and kidney.
- cotyledon (köt'i-lē'dun). A seed leaf of a plant embryo. A first leaf of a seedling.
- cross-breeding. Hybridizing. Breeding together two distinct lines of plants or animals.
- crossing-over. The shifting of genes from one chromosome to another through the breaking off of portions of chromosomes and the attachment of these portions to other chromosomes (page 669).
- cytoplasm (sī'to-plaz'm). All the protoplasm of a cell except the nucleus.

deciduous (de-sid'u-us). Falling away at maturity or at specific seasons or stages of growth, as antiers, hair, teeth, petals after flowering, fruit when ripe, leaves in autumn. Trees that drop their leaves are spoken of as deciduous trees.

- deficiency disease. Any disease caused by a lack of vitamins or other substances necessary for normal growth and maintenance.
- deliquescent (dĕl-i-kwĕs'ent). A term applied to a tree that develops large branches into which the trunk dissolves. Such trees become broad and round-topped (e.g., apple, maple).
- dendrite (děn'drīt). One of the short, branching, protoplasmic processes from the body of a nerve cell.
- diaphragm (dī'a-frăm). A thick, muscular partition dividing the ventral cavity of mammals into two parts, the thoracic and the abdominal cavities.
- differential permeability. The quality of a membrane that permits the passage through it of some substances and the exclusion of others.
- digestion. The changing of food into a form that allows it to be absorbed into and used by the body.
- disruptive coloration. Coloration which breaks up the outline of the body and protects an animal by making it difficult to see it as a silhouette against the background of its environment.
- dominant character. One of a pair of inherited characters present in an individual, which appears to the exclusion of the other (recessive) character. Dominance is not always complete, the recessive character sometimes showing and modifying the dominant character. See pages 648-655, 664.
- dorsal. Of, pertaining to, or situated on or near the back.
- ductless gland. A gland which has no excretory duct, but discharges its secretion directly into the blood (pages 502-511).
- ecology (e-köl'o-ji). The study of the relationships of plants and animals to their environments.
- ectoderm (čk'to-durm). The outer layer of cells in the coelenterates and in the early stages of development of higher animal embryos.
- efferent (ĕf'er-ent). Conveying impulses away from. Applied to nerves that carry impulses outward from the nerve centers. See page 493.
- egg. A female reproductive cell.

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- embryo (čm'brĭ-ō). A plant or animal in the early stages of its development, before sprouting, hatching, or birth.
- embryology (ĕm'brĭ-ŏl'o-jĭ). The study of the development of embryos. emotion. A feeling, as of anger, fear, pity. Also, a feeling plus the actions and other responses that accompany the feeling.
- encyst (ĕn-sĭst'). To become enclosed in a resistant, protective coating. endocrine (ĕn'do-krīn) glands. Same as ductless glands.
- endoderm (ĕn'do-durm). The inner layer of cells in the coelenterates and in the early stages of development of higher animal embryos.

enzymes (ĕn'zīms). Organic compounds in the body of a plant or animal that act as catalysts, causing the chemical processes of the body to be carried on.

- epidermis (ĕp'i-dur'mis). The outer layer of the animal skin. Also, the thin layer covering the leaves and some other parts of plants.
- epiphyte (ĕp'i-fit). A plant that lives attached to another plant, but receives no nourishment from it. Lichens and mosses that grow on trees and Spanish moss (page 898) are examples of epiphytes.
- epithelium (ĕp'I-thē'lI-um). The outer layer of a mucous membrane. In a wider sense used to include the epidermis of animals.
- estivation (ĕs'tĭ-vā'shun). Summer sleep. Dormancy of certain animals during the summer or during the dry season of the tropics. Comparable to hibernation.
- eugenics (u-jĕn'ĭks). The science of genetics applied to mankind. Concerned with improving the human race through good breeding.
- exalted virulence (vĭr'u-lĕns). Increased disease-producing power of a strain of germs.
- excurrent (ĕks-kur'ent). A term applied to trees that have a main trunk extending through the whole length of the tree. The pine and fir are examples of excurrent trees.
- exoskeleton (ĕk'so-skĕl'e-tun). An external skeleton, as in the arthropods.
- fertilization. The union of a sperm (male sex cell) with an egg (female sex cell).
- fibrovascular (fī'bro-văs'ku-ler) bundle. A bundle of tissues containing tubular cells and bast fibers, which transports food and water in roots, stems, and leaves.
- flagellum (fla-jĕl'um). A slender, hair-like extension of the cytoplasm serving as an organ of locomotion in certain protozoa and bacteria; a large cilium.
- fossil. The preserved form or other evidence of an animal or plant that lived long ago. Also, preserved ripple marks or the marks of raindrops or other natural phenomena.
- fraternal twins. Twins developed from separate eggs.
- Galley Hill man. An individual of an early Homo sapiens race whose remains were found in England. The race had Mediterranean characteristics. It is supposed to be the most important and perhaps the only component in the ancestry of modern man.
- gamete (găm'ēt). A sexual reproductive cell.
- gametophyte (ga-mē'to-fīt). The generation which reproduces sexually in plants that have alternation of generations (pages 875-876).
- ganglion (găng'glĭ-un). A collection of nerve cells.
- gene (jēn). The determiner of a hereditary unit character (pages 660-661).

genetics (je-nět'iks). The branch of biology that deals with heredity.

- germ. A disease-producing microörganism. Also, an embryo in the very early stages of development.
- germination. The sprouting of a spore or of a plant embryo.
- gill. An organ by which water-living animals absorb oxygen and excrete carbon dioxide. Also, one of the thin plate-like structures on the underside of a mushroom cap.
- grafting. Artificial vegetative propagation by joining a twig (cion) from one plant to a root system or branch of another plant. Commonly used with trees or shrubs.
- habitat (hab'i-tat). The locality or region where an individual or group naturally lives. Also, the conditions under which an individual or a group lives.
- helotism (hčl'ot-jz'm). A type of symbiosis in which one organism is held in slavery by another.
- herb. A plant having only small amounts of woody tissue and which dies completely down to the ground after maturing.
- heterosis (het-er-o'sis). Same as hybrid vigor.
- hibernation (hī'ber-nā'shun). Winter sleep; the dormant state in which certain animals pass the winter.
- homologous (ho-mŏl'o-gus). Corresponding in structure and origin, but differing in function. The wing of a bird is homologous to the fore-limbs of a mammal.
- hormones (hôr'monz). Chemical substances secreted by organs directly into the blood and carried by the blood to other organs, whose activities the hormones control. The chemical products of the ductless or endocrine glands.
- host. An organism upon or in which another organism lives parasitically.
- hybrid (hī'brīd). An organism whose parents differ from each other in one or more characteristics; the offspring of two individuals of different species or varieties.
- hybrid vigor. Increased size or vigor of hybrid offspring over the parent stocks (pages 263, 686).
- hydroponics (hī'dro-pŏn'ĭks). Same as chemiculture.
- hypothalamus (hī'po-thal'a-mus). The lower part of the midbrain, below the thalamus.
- hypothesis (hī-pŏth'e-sĭs). An unproved explanation or theory.
- identical twins. Twins that develop from the same egg.
- immune bodies. Substances manufactured by the body as a defense against infections (page 596).
- immunity. Capacity to resist or freedom from susceptibility to disease-producing organisms or poisons (pages 595-603).

indigenous (in-dij'e-nus). Native to a region; not introduced from another region. The bison is indigenous to North America and the eucalyptus tree to Australia.

- instinct. An inherited tendency to carry out a certain action or series of actions and the ability to carry out these complex actions without experience or learning (pages 712-722).
- involuntary. Independent of the will. Applied to muscles under the control of the autonomic nervous system.
- irritability. The capacity of living matter to respond to external stimuli. Islands of Langerhans (lang'er-hans). Groups of cells within the pancreas, which secrete insulin.
- karyokinesis (kār'ī-o-kī-nē'sīs). The process of cell division in which chromosomes are formed and distributed to the new cells. Same as mitosis.
- larva. The first stage beyond the egg in the life of any animal that undergoes metamorphosis especially insects (e.g., caterpillar, grub, or maggot).
- lateral line. A series of gland-like sacs along both sides of the body of some fishes. They probably provide a depth or pressure sense.
- lethal (le'thal). Fatal; causing or capable of causing death.
- linkage. The inheritance of characters not independently, but in groups (pages 668-669).
- mechanist (měk'a-nĭst). One who believes that life can be explained entirely in terms of chemistry and physics.
- medullary (měď'u-lěr'í) rays. Strands of parenchyma running out in all directions from the pith to the bark in the stems of dicots and conifers. The medullary rays serve as horizontal carriers of food, water, and oxygen.
- medusa (me-dū'sa). A free-swimming, sexually reproducing coelenterate; a jellyfish. See page 799.
- mesoderm (měs'o-durm). The middle layer of cells in the early stages of a developing animal embryo.
- metabolism (mě-tăb'o-lĭz'm). The building up and breaking down of protoplasm within a cell or an organism.
- mimicry (mim'ik-ri). An imitative resemblance of one animal to another or to some inanimate object; protective resemblance.
- mitosis (mǐ-tō'sǐs). Same as karyokinesis.
- moult. To shed the body covering (e.g., hair, feathers, skin), as in birds, arthropods, and many reptiles.
- mucous membrane. The membrane lining the cavities and canals of the vertebrate body which connect with the air. Composed of an upper epithelial layer and an under connective-tissue layer, corresponding to the epidermis and dermis of the skin.

mutant (mū'tant). An individual which differs in one or more characters from typical individuals of its own kind and which breeds true (page 663).

- mutation (mu-tā'shun). A sudden inheritable variation from the parent stock (pages 662-663).
- mutualism (mū'tu-al-ĭz'm). A type of symbiosis in which each organism is benefited by the association.
- mycelium (mī-sē'lĭ-um). The mass of thread-like filaments that makes up the main body of a fungus, as of a mold or a mushroom.
- natural selection. The selection by nature in the struggle for existence of the individuals best fitted to survive.
- nephridium (ne-frid'i-um). An excretory tubule, found in the annelid worms and some other animals.
- neuron (nū'rŏn). A nerve cell with its processes.
- notochord (nō'to-kord). A fibrous rod in the dorsal side of the body of invertebrate chordates and of vertebrate embryos. In vertebrates, the notochord develops into the backbone.
- nucleoplasm (nū'kle-o-plaz'm). The protoplasm of the cell nucleus other than the chromatin.
- nymph. The young of an insect having incomplete metamorphosis.
- oögonium (ō-o-gō'nĭ-um). A one-celled receptacle in which egg cells are produced. Applied to egg-containing cells in the green algae and some of the fungi.
- oöspore (ō'o-spōr). A spore formed by the union of unlike gametes. The fertilized egg of a plant.
- ooze. The layer of finely divided plant and animal débris that collects on the ocean floor.
- opsonin (ŏp'so-nĭn). An antibody that causes the white corpuscles to take up and destroy disease germs more readily.
- oral (ō'ral). Pertaining to the mouth.
- organ. Any part of a plant or an animal body that has a specific function and is composed of at least two tissues.
- organic acid. Any carbon compound containing the radical -C-O-H. organism. An individual animal or plant.
- osmosis (ŏs-mō'sĭs). Diffusion of substances through a semipermeable membrane.
- ovary (ō'va-ri). The organ in a plant or an animal in which the egg cells are formed and matured.
- oviduct (ō'vĭ-dŭkt). The duct which carries the eggs from the ovary.
- oviparous (o-vip'a-rus). Egg-laying; applied to animals that lay eggs.
- ovipositor (ō'vĭ-pŏz'ī-ter). Egg-laying organ of an insect.
- ovule $(\bar{o}'v\bar{u}l)$. The structure in a plant which after fertilization of the egg develops into the seed.
- ovum (plural ova). An egg.

- parallel development. Same as convergent development.
- parasite. An organism that lives in or on another organism and derives its nourishment from it.
- parathyroid (păr'a-thī'roid) glands. Small ductless glands embedded in the edge of the thyroid gland and controlling the calcium metabolism of the body (page 509).
- parthenogenesis (par'the-no-jön'e-sĭs). Development of an egg without fertilization (page 264).
- pasteurization (pās'ter-ĭ-zā'shun). The process of checking or preventing fermentation in milk, wine, and other liquids by heating to 140° or 150° Fahrenheit for 20 to 30 minutes and then cooling quickly. The advantage of the process is that the low temperature used avoids the changes in the liquid that boiling brings about.
- pectoral (pěk'to-ral). Pertaining to the chest or thorax.
- pectoral girdle. The bones which support the anterior appendages in vertebrates. The shoulder girdle.
- pelagic (pe-laj'īk). Applied to a free-swimming or floating organism of the open sea.
- pelvic (pĕl'vĭk). Pertaining to the pelvis.
- pelvic girdle. The bony arch in the lower part of the abdomen, to which the posterior appendages of vertebrates are attached. The hip girdle. perennial. Applied to plants that live year after year.
- pineal (pĭn'e-al) gland. A small cone-shaped body on the dorsal side of the brain; thought to function as a ductless gland.
- placenta (pla-sĕn'ta). The covering in which the embryo of the higher mammals is wrapped and by which it is connected with the blood stream of the mother (page 257). In seed plants, the part of the ovary to which the seeds are attached.
- plantigrade (plan'tĭ-grād). Applied to the type of foot in which the whole sole rests on the ground in walking, as in man and the raccoon (page 438).
- polymerization (pŏl-ĭ-mer-ĭ-zā'shun). The uniting of molecules of the same kind to form larger and more complex molecules (page 616).
- polyp (pŏl'ĭp). One of the individuals or parts of a colonial coelenterate (e.g., hydroids, corals). Also, a solitary coelenterate animal (e.g., sea anemone, hydra).
- protective coloration. Coloring of an animal that conceals it from its enemies or that causes it to resemble some object or other organism that is not attacked by these enemies (page 205).
- proteins (pro'te-ins). Complex organic compounds built from amino acids. A protein always contains oxygen, carbon, hydrogen, and nitrogen. Usually, in addition, it contains sulfur, phosphorus, iron, or other elements.
- pseudopodium (sū'do-pō'dĭ-um; plural pseudopodia). A temporary lobe of the protoplasm from a one-celled animal like Ameba, or from a slime mold, that is extended from the organism as it flows and creeps about.

psychology (sī-kŏl'o-jĭ). The science of the mind. Sometimes defined to include all causes of behavior and responses to stimuli in animals.

- pupa (pū'pa). The resting stage of an insect that undergoes complete metamorphosis.
- pure-bred animal. An animal with no recent ancestors not of its own breed. Pure-bred animals are more or less closely inbred. They are produced by breeding together relatives so that the blood is largely of one line.
- pure-line hybrid. A hybrid plant produced by crossing two pure-line plants.
- pure-line plant. A plant produced by self-pollination through at least several generations.
- radial (rā/dĭ-al). Spreading outward from a common center. Built in a circular manner about a center.
- radiative adaptation. The theory that new kinds of plants and animals originate by variation from the original stock and through selection become adapted to different environments and ways of living (page 89).
- recapitulation (rē'ka-pit'u-lā'shun) theory. Same as biogenetic law.
- receptacle (re-sep'ta-k'l). The upper portion of a flower stalk to which the floral parts are attached.
- saprophyte (săp'ro-fit). A plant that lives on dead organic materials.
- seed. The matured ovule. The plant structure which contains the embryo and a food supply that supports the young plant through its early developmental stages.
- self-pollination. Pollination by pollen from the same flower. Sometimes used to mean pollination by pollen from the same plant.
- self-sterility. The condition of being sterile to pollen from the same plant. Incapable of self-fertilization.
- sensory. Pertaining to the sense organs or to the sensations. Applied to afferent nerves, the impulses from which may result in sensations in the brain.
- serum (sēr'ŭm). The liquid part of the blood after a clot is formed (page 598).
- sessile (ses'il). Without a stem, as a sessile leaf or a sessile animal (e.g., rock barnacle).
- sex glands. The organs in animals that produce the sex cells (eggs and sperms) and also the sex hormones. The ovaries in the female and the testes in the male.
- sexual reproduction. Reproduction in which two gametes are fused to form a new individual (page 127).
- society. A group of animals or plants living together in the same habitat.
- soil water. Water held in the soil. Free soil water occupies the spaces between the soil particles and can be drained off. Film water is held in a thin layer on the surfaces of the soil particles.

- somatic (so-mat'ık). Pertaining to the body; the body cells and tissues as distinguished from the reproductive or germ cells.
- sperm. The male gamete.
- spermatogenesis (spur'ma-to-jĕn'e-sïs). The formation of sperms from the sperm mother cell.
- spontaneity. The power from within to originate action or a nerve impulse. Supposedly a property of protoplasm,
- sporangium (spo-răn'ji-um). The case or vessel in which asexual spores are produced.
- spore. A reproductive cell or a resting cell capable of producing a new individual. Spores may be formed sexually (by the union of gametes) or asexually (without cell fusion).
- sporophyte (spō'ro-fīt). The generation of a plant which produces asexual spores. Applied to the spore-bearing plant in forms like the mosses and ferns where there is an alternation of generation.
- stamen (stā'men). The organ of a flower or of a gymnosperm cone that bears the pollen.
- stimulus (stim'u-lus). Anything that causes a response in protoplasm; that which starts an impulse in the peripheral (outer) ending of a nerve fiber.
- symbiosis (sĭm'bĭ-ō'sĭs). The living together of dissimilar organisms.
- synapse (si-năps'). The point where the dendrites of two neurons join (page 726).
- tadpole. The larva of an amphibian. The young stage of a frog, toad, or salamander.
- terrestrial. Pertaining to the earth. Living on the ground.
- throwback. An organism that in some important characteristic resembles a remote ancestor instead of its parents.
- tissue. A group of similar cells specialized to perform a particular work. Some tissues (connective tissue, bone, cartilage, and hard tissues in plants) contain hard supporting materials built or deposited by the cells.
- toxin (tŏk'sĭn). A poisonous compound produced by animal, vegetable, or bacterial cells. Applied especially to the poisons produced by disease germs.
- transpiration (trăn'spi-rā'shun). The loss of water vapor through the epidermis of a plant. Also, the giving off of water from the lungs of an animal.
- tropism (trō'piz'm). A definite response of a plant or a plant part or of an animal as a whole to an outside stimulus.
- tuber. A short, enlarged underground stem used for storage, as the Irish potato.
- unisexual. Having only one set of sex organs, male or female, in the same organism. Not bisexual. See page 335.
- unit character. A characteristic that is inherited as a whole.

vaccine. A substance used in vaccination; any material that is injected into the body to produce active immunity.

- vacuole. Water or oil droplets within a cell. In plant cells, the space occupied by the cell sap.
- vegetative propagation. The production of a plant from a vegetative part of the parent plant. Plant production without spores or seed.
- venation (ve-nā'shun). The arrangement of the veins in a leaf (page 894).
- ventral. Pertaining to the belly or lower side of the body. Opposite to dorsal.
- viviparous (vī-vĭp'à-rŭs). Applied to animals in which the young are born in a more or less complete state of development. Contrasted with oviparous or egg-laying animals.
- voluntary muscles. Muscles that are under the control of the will.
- X chromosome. A chromosome associated with sex in many animals; the female has two, the male one.
- Y chromosome. A chromosome associated with sex in many animals; found normally only in the male.
- zoöspore (zō'o-spōr). An asexual swimming spore produced by some of the green algae and water fungi.
- zygospore (zī'go-spōr). A spore formed by the union of two similar gametes.

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